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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

Library

The annual meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn avenue, Pittsburgh, Pa., Thursday evening, January 7, 1904. In the absence of the President, Mr. Chester B. Albree, who is abroad for his health, Mr. James M. Camp, Vice-President, occupied the chair, 48 members and visitors being present. The meeting was called to order at 8:30 p. m. by the presiding officer. The minutes of the preceding annual meeting were read and approved.

The report of the Board of Directors was read by the Secretary, as follows:

REPORT OF THE BOARD OF DIRECTORS.

The Board of Direction recommend to the Society that the following names be dropped from the rolls on account of non-payment of dues: Back four years, C. H. Snyder, W. J. Knox, G. A. F. Ahlberg, W. O. Renkin, and J. B. Jenkins. Back three years, F. T. Aschman, John M. Bailey, A. F. Brown, T. G. Hamilton, K. A. Juthe, A. P. Kirtland, W. H. Ledger, J. E. Schlieper, W. E. Shrom, and P. K. Slaymaker. Back two years, R. D. Bowman.

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On motion of Mr. Emil Swensson, the recommendation of the Board was approved.

REPORT OF THE HOUSE COMMITTEE.

PITTSBURGH, PA., Jan. 7, 1904.

To the President and Board of Directors, Engineers' Society of Western Pennsylvania:

GENTLEMEN—Your House Committee beg to report as follows:

The work during the past year has been mostly the routine work assigned to that Committee, the only improvements of any note being the arranging of the room on the third floor front so as to properly care for our proceedings and current periodicals. There has been some renovating in the cellar of the building, also some papering in the rooms of the janitress. The only expense incurred has been for the lumber for the shelving in the room third floor front.

The House Committee also arranged for the rental of the two rooms on the first floor front, to Dr. Cruikshank, by the Commonwealth Real Estate Trust Co. This tenant proved undesirable and the rooms are again vacant.

Also desire to thank your President, Mr. Albree, for donating a stand for the projection lantern.

Respectfully submitted,
HOUSE COMMITTEE.
(Signed) FRED. C. SCHATZ, *Chairman.*

REPORT OF THE LIBRARY COMMITTEE.

DUQUESNE, PA., Jan. 6, 1904.

MR. CHESTER B. ALBREE, President Engineers' Society of Western Pennsylvania, Pittsburgh, Pa.:

DEAR SIR—Pursuant to your request, asking for a written report of the work done by the Library Committee during the past year, I am pleased to say this committee has done all its hands

found to do, and that was nothing.

In March of 1902 the Board was authorized to give in trust all books of the nature of back government reports to the Carnegie Library, and to place other books in cases on the second floor This action was, however, rescinded at the September meeting. In the meantime, owing to the increased attendance at the meetings, due to our rapid growth and the widespread interest of the papers read, our assembly room was found inadequate, and during the negotiations leading up to the disposal of the library the book cases and their contents were removed from the assembly room to give greater seating capacity, and, as we then thought, temporarily, to the room underneath the assembly room. These changes and marked improvements in the Society's quarters were completed in time for the September meeting, and at this or one of the subsequent meetings the Society forbade the transfer of the part of the library to the Carnegie Library, the only institution up to that time and this that showed any inclination to take it; and as a consequence, the library is still stored in the room underneath the assembly room, where it seems to serve its purpose equally as well as it did previous to its removal.

These are our excuses for inaction. Certainly, there is no room for the accessible disposition of our library in the present Society's quarters. Its return to the assembly room would materially reduce our seating capacity, which now is rarely in excess of the attendance. With a membership of 870, we have seating capacity for 125.

This committee would urge that the Society take some action as to the disposition of its library, valuable in its time, but now outclassed by the up-to-date, splendidly equipped free libraries of our two cities. It might be advisable to fit up the two rooms of the first floor, which are now vacant, bearing in mind that our lease expires April 1st, 1906, and by utilizing this space and that which can be spared of the two rooms on the second floor, make the library accessible. But, if this is not feasible, we would recommend its disposal by gift in trust, by gift outright, or by sale to the highest bidder, with such reservations of books and cases as are deemed best.

Yours truly,

(Signed) J. M. Camp.

REPORT OF THE PROGRAM COMMITTEE.

Pursuant to the requirements of the constitution for a report from all standing committees at the annual meeting, it is the pleasure of the Program Committee to report a very successful year. Papers of great general interest have been presented at the ten regular meetings of the Society, covering a broad range of topics that were deemed to be of special local interest. Twenty-eight papers were read, of which number eighteen were supplied by members of the Society, the other nine being from distinguished visitors, who kindly consented to read papers along the lines of their particular specialties. The National Bureau of Standards has contributed three (counting Dr. Waidner's paper to be presented on the 19th of this month), extremely interesting papers that will prove to be valuable contributions to the proceedings.

The meetings have been divided between those devoted to one paper per evening and those on which several short papers have been given. It is impossible for the committee to state which it considers of greater value. It can state, however, that the one paper per evening is easier on the committee.

The papers have all been on engineering topics, with as little of the political side as is possible in discussing the live local engineering subjects, and judging from the attendance at the meetings they have been what was desired.

The proceedings have not been published as promptly as they should have been, and the committee takes its share of blame in the matter. For fear that some misunderstanding may arise as to the committee's share, the following explanation of the delays is offered:

After reading a paper before the Society, the majority of writers desire to revise certain parts of their papers, and no amount of coaxing can get the manuscript from them, with the understanding, too, that they can correct the proof to suit themselves.

This causes delay number one, and generally requires two or three letters from the committee before the manuscript is turned in. This delay has amounted to more than a month in several cases.

Then the proof-reading on the part of the author of the paper and each individual taking part in the discussion takes from a week to three weeks. The committee, understand, is urging as strongly as it can all this time, the parties causing the delay, and aside from the time taken by the printer in getting out proof and then the final publication, the committee is at fault.

A great inconvenience has been experienced by the committee due to members failing to reply promptly to letters asking either for papers or suggestions, and of all members thus at fault the ex-presidents are the worst.

It is to be hoped that the new committee will not experience these difficulties, and it is with the object of calling the Society's attention to the troubles, that they are mentioned here.

Very respectfully submitted by

THE PROGRAM COMMITTEE.

(Signed) S. M. KINTNER, *Chairman.*

REPORT OF THE RECEPTION COMMITTEE.

PITTSBURGH, PA., *Jan.* 7th, 1904.

To the President, Engineers' Society of Western Pennsylvania:

DEAR SIR—Your committee for 1903 submits the following report: To have the members gather together for a social dinner, followed by informal toasts, preceding the regular monthly meetings was a feature the Reception Committee hoped to carry through the past year. The February dinner at the University Club, with but twenty-four gathered about the festive board, was too poorly attended to permit us to continue the arrangements so notably inaugurated by our predecessors. Through the courtesy of the proprietor of the Union restaurant at the Frick building, we enjoyed a bountiful spread before our April and May meetings. Forty members attended the April dinner; thirty-five the one in May. These occasions proved very enjoyable. Sparks of wit and wisdom flew with frequency. But the small attendance compelled us to reluctantly discontinue this part of the year's program.

Smokers: Three smokers were held during the year. On February 14th and May 30th they were in our auditorium. A

smoker was held on board the steamboat "Mayflower" September 25th. The average attendance at these smokers was sixty-two. Refreshments were served and there was music to enliven the occasion, with a fund of good stories thrown in that would do credit to any body of engineers. Capt. John F. Klein contributed the boat for the river smoker, giving the members an interesting view of the mill district at night.

Tour of the Frick building: On the night of April 18th over two hundred of the members inspected the Frick building from roof to cellar. Beginning with the luxuriously furnished rooms of the Union Club on the top floor, the party descended by stages. The building was found to be magnificent in its scope and appointments. The sweeping of the rooms by suction, the public safe deposit vault of the Union Savings Bank (it being the largest armor plate vault in the world), were objects of unusual interest. The plant situated in the cellar for supplying heat, light, power, drinking water, etc., proved to be an aggregation of mechanical genius. At the close of the inspection a "Dutch treat" was served in a private apartment of the Union restaurant.

Excursion to the Iron City Brewery: On Friday night, May 15th, more than a hundred enjoyed the hospitality of the Pittsburgh Brewing Company. The Iron City Brewery was visited. The opportunity to view the various processes of brewing, handling and bottling of beer was of great scientific and commercial, if not of personal interest. Besides a fine power plant, there was a cooper shop that brought forth the greatest admiration for its mechanical ingenuity. This shop was working at night especially for our members to see the operation of making kegs by machinery. At the close of the inspection a bountiful lunch was served to us during which time a real German band rendered selections.

Excursion to Brilliant: Our last excursion of the year was to the large operations about Brilliant on Saturday afternoon, October 10th. One hundred and five participated. By courtesy of the Pennsylvania Railroad, a special car was reserved, including complimentary transportation for the party, on the express leaving Union Station at 1:30. Upon the arrival at Brilliant the party inspected the city pumping station and saw the new pumps that

were being installed. The construction of the lock for Dam No. 2, on the Allegheny river, was then gone over. After an examination of the concrete walls then under construction, the Dravo Construction Company, the contractors for this work, handsomely entertained the party at a luncheon on board their dredge boat. The remainder of the afternoon was spent in viewing the Pennsylvania Railroad bridge below the station, and in going over the Brilliant Cut-Off work being done by the railroad company to a connection with the main line at Fifth Avenue. The masonry arches over Silver Lake were notable and very interesting features of the very large work then in progress.

Your committee feels that the bringing of the members together on special occasions is very desirable to the individual as well as the general welfare of the Society. We think excursions are of much benefit in showing the member what is going on and it has a tendency to keep him up-to-date.

The annual banquet of 1903 has been reported by the previous committee. Your committee is now preparing for the banquet to be held next month.

In closing our report we regret the absence of our president, Mr. Chester B. Albree, but wish him success in his quest for health in northern Africa.

Yours very truly,

GEO. T. BARNSBY,
Chairman Reception Committee.

By MR. CAMP—You have heard the reports of the committees, gentlemen. What is the pleasure of the Society?

Motion accepting reports of standing committees, with thanks, carried.

The report of the Treasurer was then read by Mr. A. E. Frost, as follows:

REPORT OF TREASURER.

The Treasurer submits the following detailed statement of receipts and expenditures, for the fiscal year ending January 7, 1904:

Receipts.

Balance, as reported January 6, 1903				$ 364 27
Dues, to January, 1901, at	$5.00	2	$ 10 00	
" " " " "	7 00	1	7 00	
" " " 1902, "	5 00	5	25 00	
" " " " "	7 00	9	63 00	
" " " 1903, "	5 00	10	50 00	
" " " " "	7 00	22	154 00	
" " " 1904, "	5 00	113	565 00	
" " " " "	8 00	541	4,328 00	
" " " 1905, "	5 00	1	5 00	
" " " 1903, "	1 75	8	14 00	
" " " 1904, "	6 00	74	444 00	
" " " " "	3 75	12	45 00	
" " " " "	4 00	18	72 00	
" " " " "	2 50	3	7 50	
" " " " "	2 00	28	56 00	
" " " " "	1 25	2	2 50	
Life Membership,		1	100 00	
Initiation Fees,		325	1,625 00	
On account			2 50	
Rent of rooms in Society-House			603 54	
Sale of Proceedings			648 05	
For binding Proceedings for members			30 50	
Badge Buttons			5 00	
Advertising			14 00	
Total				$8,876 59
				$9,240 86

Expenditures.

Rent	$1,560 00
Light and Heat	259 11
Salary of Secretary	600 00
Office Expenses	526 52
Water Tax (2 years)	107 63
Heater	150 00
Projection Lantern	144 60
Miscellaneous Improvements	130 89
Printing	1,729 80
Telephone	66 99
Stenographic Reports of Meetings	150 00
Periodicals	18 35
Total	$5,443 89
Balance	3,796 97
	$9,240 86

The above is an exhibit of the general working fund of the Society.

The amount of the building fund, with interest accrued, is	$1,247 81
Amount of lunch fund	14 74
Amount of key-deposit fund	25 00

Respectfully submitted,

A. E. Frost,
Treasurer.

Pittsburgh, January 7, 1904.

REPORT OF THE AUDITING COMMITTEE.

Your committee appointed to audit the books of the Treasurer, wish to report that they have performed that duty and have found same correct.

F. V. McMULLIN.
T. J. WILKERSON.
WILBER ALTMAN.

REPORT OF THE SECRETARY FOR THE YEAR ENDING JAN. 7TH, 1904.

Members at close of year ending January 8th, 1903	588
At the annual meeting, Jan. 20th, 1903, there were seven names dropped from the roll	7
There were thirty-four (34) resignations and six (6) deaths during the year; a total of	40
A total loss of	47
During the year nine (9) of the applicants elected in 1902 matriculated	9
There were also two (2) new honorary members elected and one member advanced	2
During the year three hundred and eighty-four (384) applicants were elected members, and of these three hundred and eighteen (318) matriculated	318
A total gain of	329
Making a net gain of	282
Total membership Jan. 7th, 1904	870

Average attendance at the regular meetings of the Society during the year was 107.

Approximate amount of dues and initiation fees unpaid and owing to the Society, $915.25.

CHARLES W. RIDINGER,
Secretary.

BY MR. CAMP—There are no more committees to report, and will call on Mr. Ralph Albree to tell us how his brother is getting along.

BY MR. RALPH ALBREE—We got a letter to-day saying that he is in very much better health. He is weighing more than he has ever weighed in his life before. If the doctors would only let him come home he would be satisfied. He is all right and feels perfectly well. The doctors, however, want him to stay there this spring.

By Mr. Camp—That is very encouraging news. The next is the election of officers. I believe that never before in the Society's life has the presiding officer, through the absence of the regular president, had the pleasure of nominating the committee to nominate himself for the presidency. The result shows that I have selected my committee well. The nominated officers are:

For President (1 year).....James M. Camp
For 1st Vice President (1 year).....Samuel Diescher
For 2nd Vice President (1 year).....G. E. Flanagan
For Directors (2 years).J. K. Lyons and Willis Whited
For Treasurer (1 year).....A. E. Frost
For Secretary (1 year).....Chas. W. Ridinger

By Mr. Camp—A motion for the secretary to cast a ballot will be in order.

By Mr. Engstrom—I make a motion that the secretary be instructed to cast a ballot for the officers nominated.

Motion seconded and carried.

By Mr. Camp—Gentlemen, I can say, like my predecessors have done, I thank you for the honor, and if I fill the office as well as the average of my predecessors I will be doing very well. We have Mr. Albree's paper, sent on here by him from Gibralter. I will call on the Secretary to read it.

PRESIDENTS' ANNUAL ADDRESS.

TO THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA FOR THE YEAR 1903.

Gentlemen—Circumstances have prevented me from being present during our meetings since the summer vacations, but the good work has continued under the care of your worthy vice presidents.

It has been a year of phenomenal growth in the annals of our Society, not only in the wonderful increase in our membership, but in the high character of the papers presented and the establishment of two additional sections, the Mechanical and the Structural. Our old standby Chemical Section has been reorganized, uniting with the Pittsburgh branch of the American Chemical Society in joint meetings, and their meetings have been well-attended.

The social features have not been forgotten, and opportunities have been frequent for meeting each other for conversation and entertainment. During the meeting of the American Society for the Advancement of Science our Society tendered them a smoker on Capt. Klein's vessel, which was very enjoyable.

The successful work of the year has been due to several causes, all contributing to the welfare and growth of the Society. Among the principal may be mentioned the earnest and diligent efforts of the different committees, and of their chairmen; to the careful and excellent papers that have been presented; to the interesting and instructive discussions following their presentation, and above all, to the presence at every regular and sectional meeting of large and interested audiences. Minor causes have been the great improvement in the appearance of our Society rooms, the acquirement of a first-class electric lantern, the lighting of the premises with electricity, and the promptness in the publication of our transactions and the enlarged circulation among our engineers and the advertisers who have used it. Our exchange list is growing, and we have very frequently had requests from far

off societies, libraries, colleges, etc., to include them in our list.

I will not attempt to recapitulate the work we have done. Our transactions have placed it before those of us who were not fortunate enough to attend the various meetings. I shall not give you the statistics of the year, which you have already had in the reports of the secretary and treasurer, and from the chairmen of committees. I can only say that the wonderful record of the year has been a great source of pleasure to me. That the association with you all, and the hearty coöperation of officers, committee members, sectional officers and members, have made the year a memorable one in my life, and that the future looks rosy for our continued forward progress.

It is expected that a president's retiring address shall be a species of final paper on some technical question. Instead of discussing any special engineering matter with which I am familiar, I wish, in view of the early establishment of the Carnegie Industrial or Trade School, to present to you a brief outline of the methods and equipments of similar schools in Germany as being of timely interest. While in Europe last summer I visited several such schools in different cities, and, through the courtesy of the Directors, was enabled to examine carefully the curriculum, methods, equipment and management of different types of schools—from the lower grade for workmen to the higher ones for industrial art workers, and for the education of superintendents, managers and foremen. The year books, or, as we call them, "catalogues" of the different schools, contain full information as to the courses of study—and I have made free use of them in preparing this paper.

The different German states maintain the larger schools, and the cities the lower grade schools, but in all of them the scholars pay tuition. Non-residents pay about one-half more than residents.

I will describe first the lower trade schools, known as Gewerben-schulen (work school), of Dresden and Nuremberg, following with the higher grade schools of Chemnitz in Saxony, as being typical, and follow with descriptions of the art industrial schools, or Kunst-gewerben-schulen of Dresden and Nuremberg, and of the museums in connection with them.

Starting with the lower grade school of Dresden, I found it located in the newer residence portion of the city, in a fine new building, surrounded with lawns, and equipped with well lighted and ventilated class rooms, lecture hall and laboratories. As yet the only shops are devoted to electrical work, but later shops for machine and wood work are to be added.

Only boys are admitted, and they must present certificates from the primary schools, or pass an examination, showing equivalent attainments. There are two main classes of scholars. The day scholars, pursuing prolonged courses, and the evening scholars, averaging about two years older, and nearly all engaged in practical work during the days. Their hours are from 7:30 to 9:30 each evening, and from 7 to 9 a. m. and 10:30 a. m. to 2 p. m. Sundays.

The day scholars, averaging about 15 years old when entering, can take either of three courses. First, the general course, for bakers, butchers, servants, cooks, and other non-technical trades, with instruction in free hand drawing, physics, arithmetic, geometry, history and geography, German language, French, English, bookkeeping and writing, with a total of 34 hours per week for two half years.

The second, building workers' courses, for plasterers, carpenters, masons, bricklayers, tinners, plumbers, etc., embracing three half years' work of 36 hours per week, embracing free hand drawing, sketching, geometrical and projectional drawing, elementary physics and mechanics, elementary chemistry, building materials and methods, algebra, geometry, history, geography, German language and writing, elementary bookkeeping and reckoning, French, English and modeling. Third, for metal workers, such as blacksmiths, machinists, moulders, etc. This course is, in general, the same as for the building trades, except that study of mechanical materials and methods are pursued.

Still further extensions of two half years are optional, embracing greater mathematical study, physics, and detail of the different trades, with laboratory practice in electrical work, for those who have completed the metal trades courses.

The year is divided into a summer and winter term. Students attending during the winter term must work practically in

some shop or on building work—learning the craft they have chosen during the summer—and must present written evidence of such time spent in working before being permitted to continue the next term's work. The summer and winter terms are therefore alike, but attended by different sets of students. I was told by the superintendent of the school, Herr Arnold Kuknow, that the combination of six months actual outside work, for wages, with the course of study of six months following, continued for the two years, had proved much more efficacious in turning out capable, intelligent, skilled workmen than the method of giving trade instruction in addition to the study in the schools.

The evening classes pursue similar studies, but necessarily can not cover the ground as fully as the day classes. Both classes of scholars hear lectures on political economy and kindred topics, embracing laws relating to employees and factories, insurance plans, manufacture and distribution of products, finance and banking, forms of government, taxation, military and naval equipment and service, etc., etc.

Excursions to large industrial works, in charge of instructors, have been found an excellent means of giving instruction and arousing enthusiasm. In 1902 and 1903 there was an average of 25 scholars in each day course, and five to six times as many in the evening classes. The total number of day scholars in summer term in 1902 was 111, and evening scholars 725. In the winter term, day scholars 196, evening scholars 663.

The scholars learn the practical part of their trades in two or three ways. Certain trades guilds have established trade schools, equipped with proper machinery and tools, to teach their own craft. These schools teach only the manual part of the work, and are maintained by the tuition fees of apprentices and from the treasury of the guilds. In general, they are only open to sons of guild members.

The building trade scholars generally work on actual building construction during the summer. The metal trades scholars work in factories as apprentices. None of them can obtain master workmen's certificates without having had the manual training.

To especially bright and ambitious students, further courses are open, at Chemnitz, a large manufacturing city of Saxony,

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about 100 miles from Dresden, where students are trained sufficiently to become competent superintendents and foremen. These schools will be described later in this paper.

I asked the Director if they had departments for girls, and was informed that there were schools for girls where they could learn sewing, embroidery, tailor work, cooking and household work, etc., but that they were maintained by the ladies of Dresden, without municipal assistance.

I asked also if there were manual training departments in the primary schools, such as we have here in Pittsburgh and Allegheny. He said in one or two of the lower schools a little had been attempted in that direction, but not much, as the Gewerben-schulen system later served better.

They have a system of honors, consisting of a silver medal for the very best student, book prizes for others, and honorable diplomas or certificates for those still lower in standing. These are highly esteemed and serve as a real stimulus to the students. The laboratories are fairly equipped with models relating to the different trades, and a good library with nearly all periodicals, technical and trade literature, in German, French and English, in comfortable quarters, is maintained and well used.

The whole tone of the institution is practical and progressive. It is maintained by the city of Dresden.

THE NUREMBERG TRADE SCHOOLS.

The Nuremberg school now occupies rather poor quarters within the old fortifications, but a fine, large building is in course of erection outside the walls, near the new Kunst-gewerben-schulen Industrial Art School.

Three general courses are offered. First, for the building trades, second for the metal working trades, and third for evening study. The school closes in summer, when all the scholars must work practically at their trades. The building courses last five winter terms. The metal trade schools for but three winter terms. The scholars must be at least 15 years of age, and must give certificates for standing from the lower schools, or pass an entrance examination. They must have the consent of parents or guard-

ians to attend, and must present evidence of actual work at their selected trade for at least one summer.

The cost is 39 marks (about $10), and scholars must find their own paper, books and drawing materials, and board and lodge themselves. On completion of courses, certificates as to the knowledge of both scholastic and manual attainment are given.

The courses of study are much similar to those described for the Dresden schools, except that more time is given to study of the details of each trade, with thorough instruction in drafting pertaining thereto. Fifty hours a week are required. The building trades scholars take up 30 different subjects in the five terms, and the metal workers 17 in their three terms. The sub-divisions include the following trades: House carpenters, finish carpenters, machine wood workers, plasters, bricklayers, stonecutters and masons, railroad engineers and firemen, mechanics and machinists, stationary engineers, house-smiths, machine blacksmiths, electricians, etc., etc. There were about 600 day scholars in both 1901-2 and 1902-3. The work in mechanical and architectural drawing shown me was excellent, done with the greatest of care, well lettered and accompanied by full explanations in round writing.

The evening classes have both a summer and winter term; the former having an attendance of about 250 and the latter of about 410 scholars. The cost is but 4 marks, or $1 per term. There are 14 different classes open, commencing with free hand drawing, and including mechanical and architectural drawing adapted to various trades. Very few actual studies are taken up, but the instruction in drawing includes explanation of the functions of the parts drawn, their strength, weight, cost, etc.

Visits of classes were made to many different works, to examine the machinery and process in operation.

A comparison of the Dresden and Nuremberg trade schools shows decided differences in length of courses, studies taken up, etc., and further, a great difference in the proportion of day and evening scholars.

In Dresden the evening scholars outnumber the day scholars, while in Nuremberg the reverse is true. It will be noted that the evening courses in Nuremberg are principally devoted to instruction in drawing, while at Dresden various studies are taken up.

I simply call your attention to these differences that you may draw your own conclusions as to which system is preferable—as the province of this paper is merely to record what I observed. The catalogues give most complete information as to scope and extent of each study taken up in the schools, and any desirous of studying the subject in detail can obtain copies upon application to the Directors of the schools.

THE CHEMNITZ SCHOOLS.

The Royal Trade Schools of Chemnitz, Saxony, offer several courses, and are maintained by the government of Saxony and from tuition fees. The lower schools offer three half-year courses in mechanical work and electrical work, and a four half-year course in building trades. The entrance requirements are very similar to those of Dresden and Nuremberg—by certificate from lower schools or examination. The building trades course sets 15 as the minimum age, and the mechanical electrical courses 17 years. The former requires at least two half years of actual building practice and the latter three half years' practice. All must have been vaccinated. Tuition is 30 marks, or $7.50 per half year.

The preliminary examination for those not having school certificates includes reading, writing and German composition, arithmetic through decimals and percentage. Written evidence of practice at actual work is required in all cases. Accident insurance can be obtained from the Directors for from $\frac{1}{2}$ to $\frac{3}{4}$ marks per half year. Books, drawing papers, etc., cost from 30 to 50 marks ($7.50 to $12.50) per half year, and board and lodging in Chemnitz from $100 to $150 per half year. Military service can be deferred until completion of courses, for students in good standing. Both summer and winter courses are held.

The mechanical course requires 40 hours per week, and is more thorough than in the schools of Dresden and Nuremberg. For the first year, arithmetic completed, plane and spherical geometry, elementary physics, geometrical and projective drawing, free hand drawing, German composition and literature. Second year, logarithims, plane and spherical trigonometry, elementary mechanics, physics, machine construction, mechanical drawing, free

hand drawing, German literature, and history, surveying. Third year, mechanics, including equilibrium, laws of motion, hydraulics, gaseous bodies, and strength of materials, machine design, mechanical drawing, free hand drawing, and modeling in plaster and wax, German literature and history, factory accounts, time and cost keeping, building construction, surveying, with field practice in leveling, plotting, earthwork calculations, and hydraulic work. Here, as in the other schools, one half year is devoted to studies and the other to practical work learning their trades.

During the half years lectures and instruction are given two to four hours weekly in the details of the following arts: Electric appliance manufacturing, electrical manipulation, telephony and telegraphy, water power plants, machine tool construction, brewery work, paper making, fire extinguishing, spinning, weaving and woolen and felt goods manufacturing. The students have option as to which course of lectures they will attend.

The electrical course is, in general, similar to the mechanical course described for the first three half years, but an additional half year is required, embracing detailed study of telegraphy and telephony, electric measurements, and the design and management of electric power and lighting plants, laboratory work in construction, testing, etc., of electrical machinery, actual practice in running electric plants, wiring and installation of motors, switchboards, etc., etc.

The same optional lectures are open, as already described, for the mechanical courses. It will be easily seen that those completing these courses, and the outside actual practice required, are certainly prepared to become very high class skilled workmen, if not foremen and superintendents, and yet there is a still higher school in Chemnitz for the special purpose of educating men to hold such positions. The courses offered are on a par with some of our high grade technical colleges, and yet they only give the degree of master workmen. For the degree of engineers one must attend still higher technical colleges at Dresden, Berlin, Freiburg, etc., but this paper will not discuss this latter class.

Returning to the Chemnitz lower schools, we find the building trades schools, already mentioned. The admission requirements are the same as for the mechanical and electrical courses,

except as to age and character of previous trade training. The five half years work is quite comprehensive in its scope, as may be seen in the outline I now give: First year, general building construction, and purposes of buildings, such as residences, farm buildings, churches, theaters, mills, factories, public buildings, etc., elementary architectural drawing, free hand drawing from copies and models, arithmetic, geometry, projective drawing, physics, German language. Second half year, building construction continued, stone work and brick work, wood construction, building laws, architectural drawing, sketching plans and details for buildings, free hand drawing, perspective, physics, and German language, including business correspondence and specifications. Third half year, building materials, chemistry, stone and wood construction, designing and architectural drafting, heating and ventilation, free hand drawing, trigonometry, strength of materials, grapho-statics, surveying, building laws, German literature. Fourth half year, construction details, estimating quantities of material and labor, designing and drafting, free hand drawing, perspective, elementary mechanics, use of hand and text books, fire extinguishing and fire proofing. The half yearly practice in some practical department of building work must accompany each half year of study. Again, we wonder at the completeness of the course offered in this under school, and understand better why our best workman in the finer building trades are so largely Germans.

THE ROYAL INDUSTRIAL ACADEMY OF CHEMNITZ.

These schools are for the education of young men who desire to become manufacturers, managers, superintendents or designers in works. Courses are offered in mechanical arts, chemical arts, building construction and electrical work. The first three courses require seven half-year terms and the latter eight half-year terms. Each course requires from one to two years previous practical work, and certificates from the gymnasium courses, or passing an examination in German grammar and composition, algebra to quadratics, French grammar and translation. Those finishing the courses will be admitted to the engineering schools of Dresden, Berlin, Darmstadt, Freiberg, etc. The tuition is 80

marks ($20) per half year for Saxons, 150 marks ($37.50) for other Germans, and 250 marks ($62.50) for foreigners. Board and lodging from 600 to 800 marks ($150 to $200) per half year, in private houses.

Not to burden you with too much detail, I will only give the course of study for the mechanical arts course, the others being very similar, with changes in the specialties of each course.

Mechanical Course—German language, history and literature, free hand drawing, sketching, oil and water colors from nature and life, building construction and drawing, business methods, bookkeeping, banking, etc., geometry, trigonometry, algebra, sterotomy, descriptive and analytical geometry, differential and integral calculus, geometrical and projective drawing, theory and practice of surveying, physics complete; chemistry, organic and inorganic, including study of fuels, lubricants, illuminants, etc.; technical lectures in machine practice, boilers, furnaces, steam and gas engines, pumps, air compressors, belts, gearing, etc., etc.; theoretical and applied mechanics, machine design, with drawing and calculation; mechanical technology, including strength of materials, tests, forging, founding, rolled material, study of woolen, cotton and silk machinery, grapho-statics, bridges, roofs, mill buildings, etc., standard machine and engine details, machine design, with calculations as to strength, action, weight, cost, etc., etc., of machinery, electrical generators, motors and lighting plants, etc. Optional choice is given of lectures on on French, English, mercantile accounting and business methods, aid to the injured, hydraulic power plants, tool construction for iron and wood work machinery, paper making, electrical work, spinning, weaving, dyeing, bleaching, etc. The average attendance required is 34 hours per week.

The electrical course contains an extra half year, almost entirely devoted to laboratory work and to the management and manufacture of electrical apparatus. The attendance is large, and students come from all over Germany and Europe. The graduates, as a rule, occupy important managerial positions in the manufactories of Germany, and the school has an international reputation. As I said before, the education approaches closely to that of a full-fledged engineer, yet that degree is not given.

Enough has been described to show how very thorough are the courses open to German youth, and to explain why their craftsmen, backed by shrewd financial and commercial management, have made the phrase, "Made in Germany," known throughout the entire world. Their system has been a gradual growth, and certainly seems admirably suited to the needs of the people, and well worthy of our careful study.

SCHOOLS FOR INSTRUCTION IN ARTISTIC TRADES.

I will now pass to the schools for instruction in the artistic trades. The prominence of French and German decorative work is mainly due to the excellence of design and of workmanship. That these qualities are due partially to inherited artistic ability and to the potent influence of artistic surroundings, must be admitted, yet to design and execute artistic work requires thorough training, and the Germans have recognized this want by the establishment of Kunst-gewerben-schulen, or Industrial Art Schools. They are to be found in nearly all of the large German cities, and the courses are modified to suit the manufacturing products of the respective neighborhoods.

I was enabled to examine in detail the schools of Dresden and Nuremberg. The Kunst-gewerben-schule of Nuremberg is housed in a large and beautiful building, outside of the city walls, but surrounded by lithographic, furniture, and other works. There are fine class rooms, drafting and modeling rooms, lecture hall, library and other rooms. There is a small but good collection of plaster models illustrating the various styles of plastic ornaments.

In Nuremberg, and open to the students, is a fine, large Gewerbs-Museum, or Industrial and Decorative Arts exhibit, containing both antique and modern samples of furniture, tapestry and textile goods, metal and glass work, china, wood and stone carvings, book bindings, reproductive arts, wall papers, bronzes, goldsmiths and lapidaries work, etc., etc., admirably arranged for comprehensive study of style and design. The Museum building is itself an exhibit of what such an institution should be.

There are four courses offered in the school—a primary one year course in free hand drawing, modeling, study of ornaments

and architectural style, geometry, etc., for workmen in artistic trades. Three courses of three years each are provided for those expecting to become master art workmen. First, the architectural school, embracing knowledge and use of architectural forms and styles, but not including structural and engineering features. It includes free hand drawing, architectural drawing, study of orders of architecture, styles of decoration and ornament, shades, shadows, and perspective, modeling, ornamental detail drawing, sketching from model, nature and life, color schemes, history of ornament, and library study of architectural books. Second, a school of decoration, much similar to the course described, but with especial attention to outline and color designs for wall papers, carpets, rugs, etc., and for lithographic and engraving work. Third, a school of modeling, embracing much of the same general course, with special attention to modeling for architectural work, furniture, ornaments, etc.

There is still another course, embracing a general knowledge of ornament, architecture, and especially of drawing and painting for the education of teachers of drawing. The courses comprise a great deal of actual work by the student from still life groups, models and life, under the guidance of the professors, of whom there are quite a number. The students are obliged to work about seven hours per day, but often do more, when daylight permits, so necessarily each student's progress is individual. Annual exhibits of students' work, largely attended by the public, are held, and prizes and honors awarded to those excelling in the different lines of work.

There are also evening courses for workmen in the art trades, such as lithographers, color printers, furniture makers and carvers, stone and wood carvers, engravers, book binders, china painters, etc. Free hand drawing, perspective, ornament, geometry, etc., are included in the course, with lectures on applied art. In 1903 the evening class numbered about 90, while the day classes were quite small, only from six to 10 in each school.

Nuremberg is rich in museums of industrial work, for in addition to the Gewerb-Museum, already described, there is the famous Germanic Museum, containing one of the finest collections of antique, mediæval architectural and domestic works of art,

in the world. There is also a Mechanical Museum, with working exhibits of machinery of all kinds, gas and steam engines, etc., etc. The Railway Museum, occupying a city square, is most complete Every phase of railway work is in evidence, exhibited by real objects, photographs, models, charts, etc. I spent an entire day examining the railway carriages, locomotives, switch and signal systems, models of bridges, culverts, trestles, telegraph and telephone systems, etc., and then did not see half that I would have liked to see.

With all these advantages, it was surprising to see the Art Industrial School with so few students. Perhaps the reason is that Nuremberg is essentially a manufacturing city, and the young men prefer the trade schools and actual work, to the larger courses in the art school, requiring the devotion of three years without being able to earn anything. The students averaged from 17 to 20 years of age. The school is maintained by the city, and certain funds are used to pay tuition fees of poor students.

THE DRESDEN ART INDUSTRIAL SCHOOL.

This school is housed in an old building in the heart of the city, and contains also the Gewerbs-Museum. It has been established over 25 years, and a handsome new building is now being erected in the newer part of the city, with adequate accommodations for the growing needs of the school. The courses are somewhat similar to those in Nuremberg, but are a little wider in scope. Both day and evening classes exist, the latter having much shorter and more elementary courses. For day classes there are 10 courses offered: 1, Architectural work; 2, Ornamental modeling; 3, figure and art modeling; 4, ornamental metal work; 5, frescoe painting and decorating; 6, tapestry and woven stuff designing; 7, porcelain painting, lithographing and color printing; 8, general industrial art designing; 9, scene painting and figurative allegorical painting; 10, class in architectural carving and modeling.

These courses occupy four semesters or half years, the students averaging about 21 years of age. The cost of tuition is 30 marks per semester for residents of Saxony and 95 for non-residents. Some 106 students were enrolled in the various courses

in 1902 and 1903. The average time per day is about six hours, but many students work even more. All students, in addition to the special work in their selected departments, attend lectures on the history of decorative arts, and the different styles and epochs, on anatomy of men and animals, and especially illustrated lectures by pictures and examples of the styles of ornament.

The museum of industrial art in connection with the school occupies the entire first floor, and while not so large as in Nuremberg, is most admirably selected and arranged, and embraces all kinds of work, being especially rich in ceramics and woven materials, as suited to the needs of Dresden. The students make great use of this museum, not only having articles in the studios upstairs, as models, but also directly in the museum, where in every corner may be seen students hard at work studying some bit of rare china, oriental rug or charming mediæval carving. The work of the students is wonderfully good and interesting, and the enthusiasm shown is unusual. The collection is not only of great interest to the industrial art student, but as well to the antiquarian and historical student.

In Dresden are other museums of world wide renown, notably the famous Dresden Picture Gallery, containing many of the world's masterpieces; the china museum, showing clay and porcelain wares of all ages and styles, and particularly rich in Dresden china. The museum of arms and weapons, rich in old tilting armor for horse and man, and the famous green vaults, or museum of jewelry work and small bric-a-brac of every description, most of it having been presented to various kings of Saxony during the last 400 years.

The combination makes Dresden rank with Berlin, Paris and Munich as an art center for both high and industrial art.

The evening classes are very well attended by youths of an average of 20 years old engaged in all kinds of industrial art trades. The courses offered embrace architectural drawing, modeling, ornamental designing, drawing and painting from still life and living models. Some 250 took the evening courses in 1900 and 1901.

It is noteworthy that in these Kunst-Gewerben-schulen the students have little book studying, the work being nearly all actual

practice in drawing, modeling, painting, carving and designing. It is supposed that the regular common school education has been attained by students. Many of them have attended the trade schools as well, before entering the art industrial schools.

I have not attempted to do more than give a general outline of the schools as I found them, and regret that I was unable to visit the Berlin Gewerb-schulen, as I understand they have most complete work shops attached, that would have been extremely interesting. But I trust that I have given you some idea of what our German competitors for the world's markets are doing, and of how necessary for our future welfare in the industrial world such schools are.

Owing to the munificence of Mr. Andrew Carnegie, one of the most far-sighted men of the world, we are soon to have a Gewerb-schule here in Pittsburg, which I trust will be the equal, if not the superior, of any similar school elsewhere.

I thank you all most heartily for the great honor you conferred upon me in choosing me for your presiding officer during the year just past.

CHESTER B. ALBREE.

Algiers, December 20th, 1903.

BY MR. SWENSSON—I deem it the next thing before us is to offer a resolution for a vote of thanks to the officers of the Society who served last year, including especially Mr. Albree's paper, which was indeed very interesting, and which he went to the trouble to prepare when traveling for his health, and that a copy of the resolution to be transmitted to Mr. Albree?

Motion seconded and carried.

BY MR. CAMP—I will announce the regular committees, so the active work of the Society can start at once. They are as follows:

Program Committee—J. K. Lyons, Chairman; S. M. Kintner, Willis Whited, F. I. Ellis.

Reception Committee—Geo. T. Barnsley, Chairman; Thos. H. Johnson, Morris Knowles, David M. Howe, Clifford B. Connelly, Capt. W. L. Sibert.

Library Committee—S. M. Kintner, Chairman; H. W. Craver, N. W. Storer, Chas. Worthington.

House Committee—F. C. Schatz, Chairman; S. Diescher, Daniel Ashworth.

Before we adjourn, I would like to call the Society's attention to that red line on the diagram showing the Society's growth and say the reason that is a tangent line is due to your own efforts, and I would like to have that line still continued up at that same angle. There are many more desirable men to be added to our Society, and I wish the good work to continue in the coming year as in the past. We almost doubled in the last year. We can hardly hope to double again, but we can make the same numerical increase. Is there any other business before the Society before we adjourn?

By Mr. Swensson—I move we adjourn.

Motion seconded and carried.

CHEMICAL SECTION.

Pittsburgh, Pa., Jan. 21st, 1904.

The twelfth annual meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held this evening at their rooms, 410 Penn Avenue. Mr. H. W. Craver, Chairman, presided.

Minutes of the eleventh annual meeting were read and approved.

Address by the retiring Chairman, Mr. H. W. Craver, on "The Constitution of Matter."

THE CONSTITUTION OF MATTER.

BY HARRISON W. CRAVER.

A fascinating subject for speculation, ever present to the philosopher and student of nature, is that of the constitution of matter. One of the earliest questions asked, the answer has never been found, and to-day we can but speculate as to what is the ultimate composition of the material world about us.

Although the question is unsolved, or, rather, although our hypotheses are unproven, we have made notable advances in recent times in our knowledge of this problem. These advances have been made chiefly by the study of the phenomena occurring when electric discharges take place through rarefied gases, and those shown by radio-active bodies. In this paper I have attempted a brief survey of the more important results of this study, especially as they relate to this question of the constitution of matter; a question of peculiar interest to us as chemists.

Ever since the beginning of philosophic inquiry concerning natural phenomena there has been speculation on this question. If we divide and re-divide a substance we must, it seems, arrive at a final state of subdivision beyond which efforts will be unavailing. The ancient philosophers who studied this question decided that matter consisted of minute corpuscles or atoms of fixed properties; the combination of these gave all the infinite variety of substances which we know. This was only speculation, however; it led to no experiments, and for centuries had but little or no effect on science.

This idea that matter was atomic in structure finally took definite and satisfactory shape as enunciated by Dalton in 1803. His hypothesis was tested by all means then known, it answered all conditions, and the "atomic theory" was adopted as a definite basis for chemical work.

There seems always to have been in circulation an idea that in the last analysis all substances would be found to be merely forms of one base. This idea has sometimes been the ruling hypothesis among the thinkers of the day, at others it has been discredited by the leaders. In the time of the alchemists it formed the basis of their hopes, for if all metals are at bottom one substance, is not their transmutation a possibility? So the alchemist toiled through years to find the secret which would give him gold, only to meet with disappointment at the end. Finally chemical endeavor turned to more profitable fields and left at rest this fascinating, but difficult, problem.

Dalton published his hypothesis, and gave a working basis, yet the question of the constitution of matter remained. It was all very well to say that matter is composed of atoms, but if we do not know the composition of an atom we have only gone forward one step toward our goal. Are the atoms of various elements seperate and distinct, or may they not be forms of still more minute and elementary substances? What is their form?

Such questions began to be asked soon after the atomic theory was brought forward. Prout studied the early atomic weights, noticed that nearly all aproached closely to whole numbers, and suggested that if they were correctly determined all would be found exact multiples of the atomic weight of hydrogen, and that hydrogen might ultimately be found to be their basis.

This suggestion provoked much discussion in the chemical world of the day. Finally, chiefly through the labors of stars, it was shown that in many cases the differences from whole numbers could scarcely be due to experimental errors, and the idea of finding in hydrogen the base of all things was abandoned. It has not been entirely forgotten, however, and has come up from time to time with different units—one-half, one-fourth, one-ten thousandth of the hydrogen atom.

Later the periodic system of Mendelèeff and Lothar Meyer showed strange relationships between the elements which suggested that they were forms of a common base.

The atomic theory has proved a firm foundation for chemical work, it has allowed a plausible explanation of observations, and thus a tendency arises to treat the Daltonian atom as the limit of divisibility, and to forget that no direct proof of indivisibility has geen found. We only know that these atoms act as though unchangeable through all chemical manipulation.

While the atom ratifies the needs of the chemist, the physicist has not found it sufficient, but has gone on speculating and experimenting as to the nature of matter, and various hypotheses have been advanced as new facts which required explanation were learned.

During recent years much attention has been directed to electrical phenomena, among others to those appearing when currents are passed between electrodes in tubes containing rarefied gases. Under such conditions a radiation occurs known as "cathode rays." In seeking an explanation of these rays it was suggested that they were composed of unremoved atoms of the original gas which were rapidly projected from the negative pole in the form of ions.

When, however, in the course of his work upon these cathode rays, measurements were made by Professor J. J. Thomson which gave an indirect determination of the size of these particles, it was found that their mass was only about one-thousandth that of the hydrogen atom. His experiments proved that in these rays the atoms are actually broken up; that the cathode rays are composed of their fragments: that no matter what the gas originally present these fragments are of identical composition and that their mass is always approximately one-thousandth that of the hydrogen atom.

Thus at last the atom was decomposed; a partial verification of Prout's hypothesis, for it seemed that all elements were compounds of one basis, even if this were a much smaller body than the hydrogen atom. The knowledge of the constitution of matter had moved on to another resting-place.

The question, What is matter? is still unsolved, for the particles which make up the atom are the limit of direct knowledge, and we can only speculate as to their composition. The leading hypothesis is that the particles are electrically charged bodies consisting of a unit charge of electricity and a nucleus of unknown composition. The nucleus of this "corpuscle" may possibly, it is recognized, be zero, and in fact Sir Oliver Lodge and other eminent physicists think that it probably is zero, and that the particles are but unit charges of electricity existing in a free state. To such an atom of electricity the name "electron" is given, in distinction to the name "corpuscle" used by those who wish to include the possibility of a material nucleus.

Now it has been found possible to detach an electron or corpuscle from an atom of matter or chemical atom, and this

electron possesses, in kind at least, the fundamental properties of the atom. This being true, it seems possible and not unreasonable to believe that electrons are the only constituent of the atom. According to this hypothesis an atom is simply a combination of electrons, the number varying for different substances, interlocked and in perpetual, violent motion, held together by electrical influences and centrifugal inertia so that they have a stable form. If the atom consists of equal numbers of positive and negative electrons it will be electricaliy neutral; if of unequal numbers, it will be electrically charged.

These electrons are extremely small; microscopic even in comparison with atoms. Compared to the hydrogen atom their sizes is as one to one-thousand, or about that of an inch sphere to one a mile and a half in diameter.

If the view that all matter is but combinations of electrons is correct, we have at last found a grain of truth in the old idea of the transmutation of metals, even if we are as far as ever from its actual realization. It may still be an improbability, but no longer an impossibility.

In the last few years much attention has been directed to a newly discovered property of some substances, that of spontaneous radio-activity. This phenomenon was first discovered by Becquerel as a property of uranium and thorium, but it is not confined to them and is present in other substances, preeminent among which is the newly discovered element radium.

Radium is found to possess emanations of three distinct kinds. One of these is similar to the Roentgen rays; that is, it consists of ether waves. Later another form was discovered, and this apparently consists in a spontaneous throwing-off of electrons just as they are shot out from the negative electrode in a vacuum tube. In addition to these already known forms of radiation, a third was recently added to our knowledge by the researches of Professor Rutherford of McGill University. This third form consists of atoms, actual atoms which have not the penetrative power of electrons, and which can be stopped by thin sheets of metal through which electrons pass with ease. These atoms are given off with high velocities; they do not seem to diminish in number or power.

At first though the fact that atoms are given off by substances does not seem so great a wonder. We know that many substances give off scents for long periods without perceptible diminution, and it might seem that this radio-activity was simply a sort of volatilization. The marvel appeared when in the course of Professor Rutherford's work the atomic weight of these atoms was determined and found to be of the order of that of hydrogen. In other words, from elements having atomic weights over two hundred are given off atoms whose atomic weight is only one or two.

The best explanation at present of this seems to be that these atoms of high atomic weight may under certain conditions break down and throw off fragments whose atomic weight will be lower.

The substance which remains is not, of course, the original atom, but a new substance; of this little is known at present. It can be obtained as a heavy gas, and is believed to again throw off atoms; in fact, several sub-compounds of the radio-active bodies are suspected. Each of these is less active than its predecessor.

Some experiments by Sir William Ramsay and Mr. Soddy have shown that one of the products of this emanation is helium, and that helium is constantly produced from radium. If this be true we have at last found an example of the long-sought transformation of one element into another.

Looking at these results from another point we are impressed that here we have a dissociation of matter and meet the elements in a process of decay. Whether there are limits to this process, whether there is a counterbalancing synthetic action at work or not, we do not know. The process is extremely slow, yet it is possibly ever acting, and the end of all matter may be to become merely a cloud of swiftly moving electrons.

Such are in brief the results of the recent advances in our knowledge. In spite of them the original question remains, for the chemical atom has only been replaced by an electrical one. What an electron is we do not know. The generally accepted view is that it is a condition of strain in

the ether, which means that ether is the basis of all matter. This would leave but one unknown link in the chain, the ether.

Secretary read the names of nominees for officers for 1904, as follows: Chairman, Mr. H. E. Walters; Vice Chairman, Mr. H. W. Craver; Secretary Mr. Geo. P. Maury; Directors, Mr. Geo. Loeffler and Mr. Chas. Rich.

On motion the Secretary was instructed to cast the unanimous ballot of the Section declaring the officers elected. After new officers had been escorted to the front, meeting, upon motion, adjourned. CHAS. RICH, *Secretary C. S.*

STRUCTURAL SECTION.

The annual meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's room, 410 Penn Avenue, Pittsburg, Tuesday, January 26, 1904.

Section called to order by the Chairman, Mr. J. K. Lyons, at 8:35 p. m., 16 members and visitors being present. The retiring Chairman, Mr. J. K. Lyons, made some remarks, narrating the origin and growth of the Section.

The Committee on Nominations appointed at the last regular meeting, Messrs. Samuel Diescher, Charles Worthington and George T. Barnsley, reported the following nominations: Frans Engstrom, Chairman; E. K. Morse, Vice-Chairman; Willis Whited, Secretary; Robert A. Cummings and F. Z. Schellenberg, Directors.

On motion, the Secretary was instructed to cast the ballot of the Section for the officers nominated by the committee.

On motion annual meeting adjourned.

Regular meeting of the Section called to order by the Chairman.

It was announced that our distinguished fellow member, Mr. Selwyn M. Taylor, had been overcome by gas and killed at the Cheswick coal mine while leading a party attempting to rescue miners who were victims of a terriffic gas explosion. He was killed at about 2 o'clock a. m., January 26, 1904.

On motion, Section adjourned, out of respect to him, at 8:50 p. m. Program postponed till the next regular meeting.

WILLIS WHITED, *Secretary S. S.*

REGULAR MEETING.

The two hundred and forty-first regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, January 19th, 1904, at 8:24 o'clock. President J. M. Camp in the chair, and 72 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership, and present same to the Society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
HARRY C. BABBITT,	Chemist, East Pittsburg Gas Works. East Pittsburg, Pa.	S. M. Kintner, J. M. Camp, C. W. Ridinger.
RALPH S. BEERS,	Electrician, of the Allegheny Steel & Iron Co., Pittsburg, Pa. h., Breckenridge, Pa.	John McGinley, H. W. Craver, J. M. Camp.
ANDREW D. BLYSHE,	Master Mechanic, Armstrong Cork Co. h., 2135 Webster avenue, Pittsburg, Pa.	J. W. Landis, John Hare, N. C. Wilson.
R. W. BRIDGE,	Mechanical Engineer, American Glass Co., Belle Vernon, Pa. h., 434 Atwood street, Pittsburg, Pa.	Robt. Linton, J. M. Camp, Frans Engstrom.
JOS. CALDWELL,	General Foreman, Punching Dept. Pressed Steel Car Co. h., 1515 Adams street, Allegheny, Pa.	H. L. Brown, G. T. Barnsley, S. Diescher.
ALBERT L. COLBY,	Assistant to President, The Oxford Copper Co., care International Nickel Co., 43 Exchange Place, New York, N. Y.	J. M. Camp, G. T. Barnsley, S. Diescher.
HENRY L. COLLINS,	Mechanical Draftsman Jones & Laughlin Steel Co., S. S. Pittsburg, Pa. h., 921 Ridge avenue, Allegheny, Pa.	D. L. Meekeel, J. L. Klindworth, P. B. Hasbrouck.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
CORRY B. COMSTOCK,	Architect and Engineer, Herrs Island. Pittsburg, Pa.	T. E. Doyle, C. W. Ridinger, W. B. Hough.
EDWARD P. COOK,	Designer, Fawcus Machine Co. h., 423 Locust street, Edgewood Park, Pa.	T. Fawcus, H. M. Wilson, G. T. Barnsley.
G. H. DANFORTH,	Assistant Structural Engineer, Jones & Laughlin Steel Co. Pittsburg, Pa.	E. K. Morse, Arthur Barnes, S. Diescher.
CLIFFORD G. DUNNELLS,	Contracting Agent, with the American Bridge Co. 802 Frick Building, Pittsburg, Pa.	L. J. Affelder, E. Swensson, S. Diescher.
FRED L. GARLINGHOUSE,	Structural E gineer, Jones & Laughlin Steel Co., Pittsburg, Pa. h., Glenshaw, Pa.	E. K. Morse, Arthur Barnes, S. Diescher.
JOHN L. HAINES,	Chief of Order Department, Jones & Laughlin Steel Co., Pittsburg, Pa. h., Glenshaw, Pa.	E K. Morse, Arthur Barnes, S. Diescher.
ARTHUR A. HAMMERSCHLAG,	Director Carnegie Technical Schools of Pittsburg, Pa., 41 Liberty street, New York, N. Y. 313 Sixth avenue, Pittsburg, Pa.	F. C. Phillips, J. A. Brashear, W. R. Ludwig.
JOSEPH D. HARRIP,	Assistant Chief Engineer, Westinghouse Air Brake Co. Wilmerding, Pa.	E. M. Herr, H. H. West'ghouse, H. C. Loudenbeck.
R. L. KENAH, Jr.,	General Manager, Pierce-Crouch Engineer Co., Empire Building, Pittsburg, Pa. h., New Brighton, Pa.	J. P. Leaf, E. F. Wendt, S. Diescher.
DAVID B. KINCH,	Superintendent, Frick Building. Pittsburg, Pa.	G. T. Barnsley, E. Swensson, M. Knowles.
WM. C. MORELAND,	Secretary, Jones & Laughlin Steel Co. Pittsburg, Pa.	E. K. Morse, Arthur Barnes, S. Diescher.
WILLIAM B. ROGERS,	President, Rodgers Sand Co., 321 Water street, Pittsburg, Pa.	G. T. Barnsley, J. M. Camp, S. Diescher.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
FRANK W. SALISBURY,	Master Mechanic, Allegheny Plate Glass Co., Hite, Pa. h., Hite, Pa.	S. H. Stupakoff, C. W. Ridinger, J. M. Camp.
IRA A. SHOFF,	Master Mechanic, Allegheny Steel & Iron Co., Pittsburg, Pa. h., Breckenridge, Pa.	John McGinley, H. W. Craver, G. T. Barnsley.
HARRY W. STEVENSON,	Chief Engineer, Wildwood Pumping Station, Penna. Water Co. h., Nadine, Allegheny Co., Pa,	G. S. Davison, H. C. Hawley, J. T. Miller.
CHAS. F. WALTHERS,	Assistant Engineer, U. S. War Department. 507 House Building, Pittsburg, Pa.	E. Schenk, H. Laub, S. Diescher.
MILFORD WORTHAM,	Assistant to General Superintendent, Lucy Furnaces, Carnegie Steel Co. Lucy Furnaces, Pittsburg, Pa.	James Scott, J. P. Collins, Bruce Walter.

Voted that the Secretary cast a ballot to elect them to membership.

The paper of the evening was then read by Doctor C. W. Waidner on "High Temperature Measurements."

The paper with discussion will be printed in a later number of the proceedings.

CHEMICAL SECTION.

PITTSBURG, PA., Jan. 21st, 1904.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held this evening with the Pittsburg Section of the American Chemical Society at 410 Penn Avenue. Mr. H. E. Walters, Chairman, presided.

Minutes of previous meeting were omitted.

Chairman appointed the following committees for the ensuing year:

Committee on Literature—Mr. W. H. Craver, Mr. A. G. McKenna, Dr. F. C. Phillips, Mr. Jacob Mohr, Mr. J. O. Handy.

Programme Committee—Mr. L. L. Arnold, Mr. Charles Rich, Mr. George Leoffler.

Committee on Methods—Mr. J. M. Camp, Mr. H. E. Myers, Mr. Kemery.

The paper for the evening, "The Gas Stove Considered from a Sanitary and Chemical Standpoint," by Dr. F. C. Phillips, was read, and proved very interesting. Dr. Phillips explained very thoroughly the action of the gases in closed rooms, where stoves had chimney connections, and where they did not have connections with chimneys.

The paper was discussed by a number of the members present.

Vote of thanks to Dr. Phillips for his very valuable paper.

Mr. Babbitt next presented a sample of liquid air, making a number of experiments which were very interesting and instructive.

No other business before the Society, on motion adjourned.

GEORGE P. MAURY, *Secretary*.

THE GAS STOVE CONSIDERED FROM A CHEMICAL AND SANITARY STANDPOINT.

By Francis C. Phillips.

In the early days of natural gas development when gas bills were moderate and the belief prevailed that the supply from the wells was unlimited, there was little need for any device for its economical utilization in the household. A gas pipe was set up over the grate bars in an open chimney or in a stove and the huge luminous flame burning freely in the air gave an abundant supply of heat by its direct radiation.

As it soon became evident that we could not accept as final the pleasant predictions of scientists who asserted that natural gas is a contemporaneous product, and therefore inexhaustible, but that we must regard it as a stored product, bound steadily to diminish from the time of the tapping of the first gas well, increased economy in its use became a necessity.

It was thought to be an import and improvement when the gas was admitted through a mixer under a grate upon which was piled a deep layer of broken fire brick or moulded balls of burned clay. Whether combustion was rendered complete by the fire brick and clay balls was not material for a chimney flue always carried away the waste gases.

In more recent times gas heating appliances of more economical form have been devised, and as at present used fall under certain general types. These may be described as follows:

1. Stoves in which the gas is burnt with luminous flames from a row of holes or burners situated at the base of the stove. By radiation from the flames the sides of the stove are heated. This form of stove has been long used for coal gas.

2. Stoves in which the gas is burnt from a row of burners under the top, the heat being reflected out into the room by a piece of sheet copper forming the back and curved bottom of the stove.

3. The gas burns from small openings in a horizontal pipe placed close against the back wall of a chimney or box shaped

stove. Or the gas vents are small openings in the hollow piece forming the back wall, and diminutive flames in great number play upward and against the back wall, which is often tilted forward to obtain a better heating effect. Connected with fhe burner in these stoves is an air mixer which serves as an important adjunct in securing complete combustion of the gas. In the common forms of stove of this type having a row of holes, a device often used consists of a cylinder of sheet iron having a great number—several hundred---of very fine holes. In the older patterns a piece of gas pipe was used having a dozen or two of larger holes.

All these forms of stoves may give satisfactory results when connected with a chimney and from a sanitary standpoint, when so used, are ordinarily unobjectionable so long as the chimney draught is properly maintained. It has become quite common, however, to use stoves of comparatively large capacity without chimney connection in dwelling rooms, and when this is done, the construction of such stoves becomes a matter of much importance. With a view to a study of the products of combustion of natural gas as used in a gas stove some experiments have been conducted and the results of these experiments are here presented.

A gas stove of a common type of construction was used. It was of box form. The burner consisted of a sheet iron pipe having about 300 very small holes along its upper surface. A mixer at the end of the burner having an adjustable air valve, served to control the air supply. The gas issuing from the burner holes formed a single sheet of flame, extending from side to side, and playing upward against a sheet iron back, coated with asbestos. This stove was set up in a room of 576 cubic feet capacity. An aluminum tube of $\frac{1}{4}$-inch bore was passed through the wall into an adjoining room and samples could by this means be drawn out for analysis. This tube was fixed with its end six feet in front of the stove and at a height of three feet from the floor. The walls of the room were calsomined.

It was noticed when the gas stove was used in this room that a strong odor was developed, and gaseous products resulted which exerted an irritating effect upon the eyes and throat. After the stove had burned for five hours in the room an examination of the air was made with the following results:

Carbon dioxide ..... 1.0 per cent.
Oxygen ..... 15.15 per cent.

During the five hours' time there were burnt 114 cubic feet of natural gas (measured by meter). This volume of gas must have produced somewhat more than the same volume of carbon dioxide, and had there been no opportunity for its escape the air in the room should have contained more than 20 per cent. of this gas. The room had been tightly closed. There was no window in its walls. The greater portion of the carbon dioxide had, therefore, made its way out through the plastered ceiling and walls. Tests were made of the air draw out from the room after the stove had been burning for a half hour. Palladium chloride paper was darkened, gold chloride solution yielded a precipitate of metallic gold. A dilute solution of fresh blood which had been shaken up with a portion of the air contained in a half gallon bottle gave indications, on subsequent testing, of the presence of carbon monoxide. A caged Guinea pig and caged rats placed in the room or exposed to a current of the air drawn out from the room, died in periods varying from one to two hours (counting from the time of lighting the stove) and their blood was found on spectroscopic examination by the method of Vogel (Berichte der deutschen chemischen Gesellschaft, 11, p. 235), and Hempel (Methods of Gasanalysis, Translated by Dennis from the Third Grman Edition, p. 211) and by Wenzel's methods (Lehmann, Die Methoden der Praktischen Hygiene, p. 153), to contain carbon monoxide. The air of the room possessed a strong odor of formaldehyde. Tests were made for this substance by passing a current of the air through a solution of aniline in water. A white precipitate was produced indicating that formaldehyde was present as a product of the burning of the gas.

It was found that whether the air valve at the mixer was partly closed or was wide open carbon monoxide was constantly produced. Its production continued whether the gas was turned down so that the flames were only two inches high or was so increased that they reached a height of eight inches. The burner used, having 300 small holes, and producing a broad sheet of flame, spreading against the back wall, was then replaced by an old style burner, having a row of 12 holes, each hole being $\frac{1}{4}$-inch

wide. In the case of this burner the flames burn separately, an air space intervening between the flames. Each flame is, therefore, surrounded by air on three sides. The gas and air entered teh mixer in a horizontal direction. When the flames were about five inches high no carbon monoxide was found in air samples taken. On increasing the gas flow so that the flames reached a height of eight or nine inches, carbon monoxide and formaldehyde were produced. The single flames constituted a decided advantage over the continuous sheet of flame, causing a more complete combustion.

In order to test the effect of the mixer in producing complete combustion the hole through which the gas escapes into the mixer was enlarged from 1-16 inch to 1-8 inch. This change was found to lead to the formation of carbon monoxide, in the case of the burner with a few larger holes. A change was then made in the position of the mixer. The burner with 300 holes was used, but the mixer in a horizontal direction. When the flames were about was directed vertically upward. Combustion was somewhat more complete, although both carbon monoxide and formaldehyde were shown to be produced as before.

The burner tube used in the first trials was turned somewhat about its horizontal axis so that the row of holes on its upper surface was moved further away from the asbestos coated back. The base of the flame sheet was then about $1\frac{3}{4}$ inches from the back instead of $\frac{3}{4}$ inch. Combustion was then found to be more complete. The flame sheet should not press too closely against the mass of asbestos at the back. Solid matter in a flame may tend to impede combustion by obstructing the access of air even when the solid exerts a catalytic action. It is for this reason that an incandescent burner may produce a small quantity of carbon monoxide in spite of the strongly catalytic action of the material of the mantle. An ordinary luminous gas flame does not produce carbon monoxide.

A gas flame has a tendency to incline towards any hard substance held at its edge or near it. The flame sheet in a gas stove is liable to press too closely against the back even when the flame at its base is far enough away from the back.

The original stove was then tried in larger rooms, of 1,500, 3,000, 4,800 and 6,000 cubic feet capacity. In all cases carbon monoxide was produced.

The pressure upon the gas was increased to 16 ounces in the room of 6,000 cubic feet. The flames then burnt 4 inches out over the top of the stove. Carbon monoxide was constantly produced. In all these trials in larger rooms the air samples used for analytical tests were drawn from the opening at the back of the stove.

While the air mixer is a very important device a great many experiments made with different stoves have shown that more dependence must be placed upon a proper air supply to the flames than upon the effect of the air mixer in attainment of complete combustion and the prevention of carbon monoxide and formaldehyde production.

In stoves which have their burners at the bottom, and producing free burning flames, combustion is usually complete, so long as the gas flow is properly regulated. Stoves having free burning flames at or near the top and a copper reflector are not always as safe as these. Flames near the top of a partly shut in stove are not so well provided with a supply of fresh air, and in this respect are less safe.

If the flames are too large and in playing against the top cause a deposit of soot, carbon monoxide production is to be feared. The upper part of such a stove should not be too much shut in by an overhanging front. The danger in the use of these stoves is lessened by the fact that care is likely to be taken to check the flow of gas below the point at which the inconvenience of soot formation is possible.

Physiological effects of the products of the combustion of natural gas.

Natural gas may be regarded as a mixture of methane with very small quantities of other hydrocarbons and about 2 per cent. of nitrogen. One cubic foot of natural gas will produce in burning a little more than one cubic foot of carbon dioxide and a little more than two cubic feet of water vapor, and there will be consumed somewhat more than two cubic feet of oxygen.

Carbon monoxide may be a product of such combustion but only in case that the process is checked either by lack of air supply

or a sudden cooling of a flame. Sulphur compounds occur in natural gas. These in burning produce sulphur dioxide. The quantity of such compounds is too small, however, to contribute towards the contamination of the air of a room in which a gas stove is burning.

In the experiments described it has been shown that formaldehyde may be among the products of incomplete combustion of natural gas in a stove.

Carbon dioxide. The effects of this gas upon health have been generally considered in reference to the case of exhaled air and it has been supposed that the ill effects of inhaling the air of crowded rooms are due to volatile organic poisons contained in the breath rather than to any specific poisonous action of carbon dioxide. Billings Mitchell and Bergey ("The Composition of Expired Air and its Effects upon Animal Life," Smithsonian Contributions to Knowledge, 1895, p. 24) have shown that the bad effects of such air are due to an increase of carbon dioxide, or a loss of oxygen, or to both factors. Bergey, (Principles of Hygiene, p. 502) states that "carbon dioxide is poisonous in large proportions exceeding 1 to 2 per cent., but there is no doubt that the presence of even smaller quantities for long periods of time induces progressive depression of vitality thus constituting a preparation and predisposing cause for many diseases." Grehant ("Les Poisons de l'Air" p. 51) found that the elimination of carbon dioxide by the lungs is diminished by about 25 per cent. when the air inhaled contains 1 per cent. of this gas. When the proportion of carbon dioxide in the air reaches 7 per cent., its elimination from the lungs ceases and the proportion in the inhaled and exhaled air remains the same.

Carbon monoxide. The poisonous effects from the inhalation of this gas are well known to sanitarians, and authorities agree as to its dangers. It is the poisonous constituent of coal gas and of water gas, and the many deaths occurring from poisoning by illuminating gas are attributable to this one substance. The poisonous properties of blast furnace gas are also due to carbon monoxide. Deaths resulting from the "after damp" which follows the explosion of fire damp in a coal mine, are due in many cases to the presence of carbon monoxide as a result of the explosion.

"Carbon monoxide has no smell or irritating properties by which its presence may be recognized, and its action is peculiarly slow and insidious The first symptoms are usually dizziness, shortness of breath and palpitation following any unusual exertion. Sometimes there is drowsiness and sometimes there is unusual excitement, similar to that produced by alcohol. When more of the gas is inhaled there is great failure of muscular power. The least exertion causes fainting and any serious exertion may prove fatal. At the same time the mind becomes more or less confused, although the person affected is not aware of any mental failure. The senses are also affected and frequently there seems to be greater or less insensibility to pain, as miners who are partially stupefied by carbon monoxide are not infrequently seriously burnt by their lamps. The loss of muscular and sensory power gradually becomes more and more complete until consciousness is entirely lost, and finally, with further absorption, death quietly ensues. There is no pain or serious discomfort at any stage. Recovery from slight carbon monoxide poisoning is usually accompanied with slight headache, nausea and depression. When consciousness has been lost for a considerable time recovery is very slow and uncertain. In cases where much muscular exertion has been attempted during exposure to the poison the heart appears to be often seriously affected." (Dr. Thomas Oliver, Dangerous Trades, p. 551.)

A more or less complete failure of the intellectual faculties is often one of the early symptoms, and the victim, although conscious, may be wholly unable to make any effort to secure aid. It has been observed that of several persons exposed to the gas those who are in the most vigorous health are often the first to succomb to its effects.

In cases of fatal poisoning patches of an intense red color appear upon the surface of the skin at different parts of the body. These are quite characteristic of carbon monoxide poisoning.

Formaldehyde.—It has proved impossible to find any records of poisoning from the inhalation of formaldehyde. It has been found that the gas largely diluted with air is very poisonous to mice and to Guinea pigs. Wood (Therapeutics, Its Principles and Practice, eleventh edition, p. 812) states that "formaldehyde

is an intensely active local irritant, producing, when in very minute amount in the air, violent irritation of the respiratory mucous membranes, or, it may be, fatal pulmonary inflammation." It cannot be asserted that formaldehyde is likely to result in such quantity from the burning of a gas stove as to endanger life, but its production even in small quantity along with carbon monoxide and dioxide may seriously affect health.

Gas stoves of faulty construction have been the cause of many cases of carbon monoxide poisoning, but accidents have been more commonly due to the use of stoves in an improper and careless manner.

A gas stove in burning generates a considerable quantity of carbon dioxide, and this gas being heated, rises and becomes diluted with warm air. Of this heated and impure air a large portion passes off from the room by diffusion through the porous plaster of the ceiling and walls; another portion remains in the upper part of the room, and a third portion in contact with the walls, grows colder, and sinks to the floor to reënter the stove and be carried again to the ceiling. Some experiments have been tried in order to ascertain to what extent the carbon dioxide would increase in a small room when a gas stove was burning continuously for a considerable period. A gas stove was set up in the room of 576 cubic feet capacity and gas was burnt at the rate of 20 cubic feet per hour. Air samples were drawn out from the room at intervals and carbon dioxide determinations gave the following results.

Time.	Carbon dioxide found.	
	Dec. 4.	Dec. 5.
1 hour.....	1.10 per cent.	0.85 per cent.
2 hours.....	1.5 per cent.	1.3 per cent.
3 hours.....	1.6 per cent.	1.7 per cent.
4 hours.....	1.6 per cent.	1.8 per cent.
5 hours.....	1.7 per cent.	1.9 per cent.
6 hours.....	1.6 per cent.	1.8 per cent.

These determinations seem to show that an approximate equilibrium had been reached between the production of carbon dioxide and its escape by diffusion, and that the proportion of this gas in the air had become practically constant.

It is probable that when a gas stove is used without a chimney connection in a dwelling room of moderate capacity of which the doors and windows are closed, the conditions are tending towards a limit as regards the vitiation of the air, this limit being dependent upon the quantity of gas burnt, the capacity of the ceiling for diffusion, and the difference of temperature between the air inside and outside the room. From a series of experiments, carried out at different times, it may be said that in an ordinary small room the carbon dioxide resulting from a gas stove may increase to about 2 per cent., while the oxygen of the air may be decreased to about 15 per cent., but in rooms of 1,500 cubic feet capacity or less, a condition of vitiation corresponding approximately to these limits is not likely to be exceeded.

Gaertner (Journal für Gasbeleuchtung und Wasserversorgung, 1900, p. 336) cites results of experiments upon the effects of a gas stove upon the air of a small room, from which it appears that air containg 2 per cent. of carbon dioxide and 16 per cent. of oxygen, together with the proportionate amount of water vapor may extinguish the flames of candles and coal oil lamps. Carbon monoxide was found to be produced.

When the oxygen was reduced to 15 per cent. combustion was so incomplete that the flames yielded much soot. It is therefore possible for the air to be so vitiated by the action of the stove itself that the gas can no longer be burnt without grave danger of carbon monoxide poisoning to the inmates of the room.

It appears, therefore, that respiration may continue for a time at least in air after it has become so vitiated as to interfere with the complete combustion of gas. We may still breathe air which has become so impoverished that gas flames can no longer burn without production of carbon monoxide or formaldehyde.

The newspapers report from day to day cases of poisoning from the use of gas stoves without flue connections. Many of the accidents from this source might be summarized in the following way: During a cold winter evening the gas is lighted in the stove. The pressure being low and the valve is turned wide open. The occupant of the room falls asleep and is found dead the next morning. The gas pressure had increased during the night and the flames play over the top of the stove when the room is opened

the next morning. Carbon dioxide accumulates to the extent which prevents the complete combustion of the gas, and a case of carbon monoxide poisoning results. Under ordinary conditions the air may not become so far vitiated as to produce such an effect. An exceptionally low temperature outside may cause moisture to condense in the pores of the plaster ceiling and thus check diffusion. Ice, covering the window cracks on the outside, may diminish the inflow of fresh air. Papered walls, and especially, varnished paper, may add to the danger. In rooms where several persons breathe and numerous gas flames are burning, the tendency to carbon monoxide production will be increased. Defective construction of the stove may still further promote the danger. With the possible coincidence of several such causes the fatal limit of contamination of the air may be reached. Combustion is then rendered incomplete and carbon monoxide is produced with its attendant consequences.

Gas stoves without flue connections can only be used with any degree of safety when of very small dimensions and when properly constructed. The little portable stoves with free burning flames and having their sheet-iron sides perforated with many small holes admitting a plentiful supply of air, are perhaps the least objectionable form for use without flues. A kettle closely fitting the top of such a stove may, by checking the draft, cause incomplete combustion and an odor of formaldehyde.

A stove of this type should have a lid, to prevent a too rapid rise of warm air to the ceiling, but this lid should be perforated in order to permit of a sufficient draught.

Some of the instantaneous water heaters produce a strong formaldehyde odor owing to the interference with combustion of gas due to the cooling of the flame as it plays against a pipe through which a stream of cold water is flowing. The same odor is noticed whenever a kettle of cold water is held in a large gas flame. Haber and Weber (Journal Für Gasbeleuchtung und Wasserversorgung, 1896, p. 102) have investigated the products from a gas flame burning closely against a kettle of water and have shown that under such conditions carbon monoxide and acetylene may be constantly produced when the air entering by way of the mixer is insufficient. Unpleasant odors are commonly noticeable

about a gas cooking stove when the flame plays against cold surfaces. There can be no doubt that besides carbon monoxide and formaldehyde other products result from the incomplete combustion of coal gas and natural gas. In an experiment with a gas stove of somewhat faulty construction, using natural gas under a pressure of eight ounces, a strong odor of isobutylene was observed. There is no reason to think that either acetylene or isobutylene is poisonous if present in small quantities in air.

Stoves in which the burner consists of a horizontal pipe with a row of holes for gas and producing flames which play against an asbestos coated back, should have a space open below between the burner and the back. The asbestos should not be packed in too dense masses. Burners with a few holes of a quarter inch in width would be preferable (if obtainable) to those having a large number of fine openings. The air mixer should be wide open for the admission of air and should not have a valve for the closing of the air opening. The draught of the stove is diminished by being compelled to take a downward course on its way to the outlet and such a course is especially dangerous when a stove is used without chimney connection.

It has been found that by using a stove pipe rising vertically to a height of six feet above the stove, and terminating within the room, it is possible to greatly improve combustion so as to prevent the production of carbon monoxide and formaldehyde. This was shown by analyses of samples of air taken directly from within the outlet of the stove.

Natural gas as derived from the West Virginia fields, and now piped to Allegheny and Pittsburgh, does not contain carbon monoxide. This fact has been fully demonstrated by careful and repeated tests and it may be safely asserted that the carbon monoxide found in the above experiments was not due to an escape of unburnt gas from the stove.

The time has come when the mode of setting and use of gas stoves in dwellings should be placed under the supervision and control of the health authorities in municipalities.

Coroner's juries in Allegheny county, who have rendered verdicts in cases of fatal poisoning caused by the improper use of gas stoves, have frequently coupled their verdicts with a recom-

mendation that a law be enacted forbidding the use of gas stoves without chimney connections. As modern houses are built, however, there are usually to be found in every dwelling several rooms without chimney flues, and as heating by gas stoves affords frequently the only practicable method of rendering such rooms habitable, the enactment of such laws would necessitate the further enactment that every room shall have a chimney flue. Gas stoves offered for sale should be subjected to tests and if found to yield carbon monoxide or formaldehyde when used with gas under varying conditions of pressure, should be condemned.

That a gas stove can be used without danger of production of the poisonous substances resulting from incomplete combustion should be attested by an official certificate, and without such a certificate its sale should be illegal. The manner of using a gas stove in a dwelling house should be as much a matter of official inspection as the plumbing.

Carbon monoxide is the most poisonous gas to which the dwellers in city houses are ordinarily exposed, and its effects are without doubt being unknowingly felt by many as the result of faulty construction and improper use of gas stoves.

[Paper read before Mechanical Section, February 2, 1904.]

SOFTENING AND PURIFICATION OF WATER.

BY J. C. W. GRETH.

The softening and purification of water have been receiving so much attention recently in scientific and engineering papers, also from engineers, that it seems no longer necessary to call attention to the fact that the impurities in water are of two kinds, viz., organic and inorganic, and may be either in suspension or solution. Those in suspension have received the most attention from engineers, and may properly be termed "the sanitary purification of water for use in cities, public buildings, etc." These present, however, an entirely different problem from the softening and purification of water for boiler-feed and manufacturing purpose, and the work is usually performed by sand filter-beds or mechanical filters. The presence of organic matter, or bacteria, either in solution or suspension, which would be detrimental to public health, would not have any injurious effects on a boiler. The inorganic matter, such as soluble lime, magnesia and iron, as well as free acids and silt or clay, do cause an unnecessary amount of labor and expense.

The usual inorganic substances in water are the following, and are grouped as to the trouble they usually cause in steam boilers: Carbonates and sulphates of lime and magnesia, silica, oxides of iron and alumina, and suspended matter. All of which tend to form scale. The following cause corrosion: sulphuric, hydrochloric, carbonic, acetic and tannic acid. The latter two are usually due to contamination from chemical works, or other processes in which these acids are either used or developed. Iron sulphate and magnesia chloride belong in a class by themselves, as they not only form scale, but are corroding agents besides.

The carbonates, sulphates and chlorides of sodium, and sometimes potassium, are found, especially sodium chloride. These substances cause no particular harm, except when they are present beyond a certain amount; in which case foaming will result. When a water which contains a part or all of these impurities is heated to 212 degrees fahrenheit, and is boiled for some time, the carbonates of lime and magnesia are precipitated; but it requires a temperature of about 300 degrees fahrenheit (or steam at 70 lbs. pressure) to precipitate the sulphates of lime and magnesia. The continual evaporation of the water concentrates these impurities, until finally the point of saturation is reached. Then the bulk of the more soluble impurities will be precipitated, together with the less soluble carbonates, sulphates, and even chlorides. This deposit of scale forms wherever the water comes in contact with the hot metal. The deposit is piled up in thin layers of iron, silica, lime and magnesia, and is generally the thickest where the least amount of steam is generated. The consequences are generally serious.

The carbonates of lime and magnesia are non-conductors of heat, having relative values of .67 and .76 (felt or wool being 1.00). It is claimed the conducting power of iron for heat is about thirty times that of saturated scale. The effect of covering the metal with this non-conducting material is:

First. The increased amount of fuel which it is necessary to use, in order to raise the temperature of the water to a given point or to generate steam.

Second. There is great danger of burning or over-heating the boiler, by reason of the fact that the water is not in immediate contact with the shell and cannot carry off or absorb the heat from the plates. The boiler being under pressure the over-heating of the metal results in the stretching of the plate, forming a bag; or the metal may blister or crystalize, which will very much reduce its tensile strength, rendering the boiler unsafe. This means repairs are in order, even in cases where the metal does not get heated enough to bag or blister, but is sufficient to cause the metal to expand unequally, distorting the seams and joints between the several

parts of the boiler. This causes leaks, which, in time, become serious enough to put the boiler out of use. Even under conditions where no disastrous results follow, a great deal of labor on the part of the engineer in charge is necessary to keep the scale from accumulating. It is usually very hard, and can only be removed after considerable hard work. Continual hammering and chipping is injurious to the metal, and even if the intentions of the cleaner are the best, it is impossible to reach all parts of the modern steam generator for cleaning.

The boilers are not the only part of the steam generating plant which are affected by the impurities of the water. A deposit of a part of the carbonates of lime, magnesia and iron takes place when the water reaches the exhaust steam heater. The same trouble arises in steam plants using economizers or heaters through which the water passes after it leaves the exhaust steam heater, and before it reaches the boilers. These obtain their heat from the waste gases of the furnace, and it is very important that their surfaces should be clean and kept so without involving a great deal of labor and expense. A deposit, too, especially from well waters, takes place in the feed pipes, valves, pumps, etc.

The action of the acids is a subject which interests us considerably on account of the surrounding rivers containing more or less, either in the free state, or loosely combined. The action is, briefly, as follows:

Sulphuric acid, the one most common, is either in a free state or combined with iron as the sulphate, which the heat immediately splits up into iron oxide and sulphuric acid. In the boiler, the acid attacks the iron of the boiler, forming iron sulphate, which immediately splits up into sulphuric acid and an iron salt, which, through various stages, eventually reaches the shape of ferric oxide, which is precipitated. The acid being set free, this, with more acid coming in with the water, again attacks the iron, and goes through the same process again, and eventually a water which might contain only three or four grains of free acid on entering a boiler, would become a strong solution and carries on its work of rapid disintegration of the iron of the boiler. These are substances, the re-

moval or neutralization of which, from water, forms the subject of this paper.

Let us first consider some of the mechanical devices and methods employed, with more or less success, in the purification of water for boiler-feed purposes.

The carbonates of lime, magnesia and iron are soluble in waters having carbonic acid in solution. When this water is heated to a temperature of 212 degrees fahrenheit, and boiled for a time, the carbonic acid is driven off and the carbonates precipitated. This fact is made use of in the ordinary exhaust steam heater, and is the reason for their being called water purifiers. These heaters are not built of sufficient size, nor is the temperature of the water really ever raised to the boiling point, nor the water kept in the heater, or at this temperature, long enough to drive off all the free or loosely combined carbonic acid; or in other words, bring about the precipitation of all the carbonates in the heater. A portion of them is removed. The following analyses, before and after going through an exhaust steam heater, of well-known make, show about the extent of the removal of the carbonates:

Analysis No. 184.

	Grs. per U. S. Gal.
Carbonates: calcium	8.3194
magnesium	3.6087
Sulphates: calcium	2.8567
Chlorides: magnesium	1.4225
sodium	1.6149
Oxides: iron and alumina	.2915
silica	.8745
Volatile and organic matter	1.9996
Total solids	20.9880
Carbonic acid in solution	5.83

Analysis No. 184-A.

	Grs. per U. S. Gal.
Carbonates: calcium	5.0632
magnesium	1.2243
Sulphates: calcium	2.8521
Chlorides: magnesium	1.4181
sodium	1.6142
Oxides: iron and alumina	.1666
silica	.4897
Volatile and organic matter	1.2346
Carbonic acid in solution	3.071

The sulphates of lime and magnesia are not affected in the exhaust steam heater, as they require a higher temperature to cause precipitation. About 300 degrees fahrenheit, or steam at 70 lbs. pressure, will bring about a precipitation. To find a remedy, or to prevent the precipitation of the sulphates in the boiler, a second tank, like a boiler filled with pans or shelves, and heated with live steam, is brought into use. Into this receptacle all the water passes before it finaily reaches the boiler. By maintaining this heater at the boiler pressure, the water becomes hot enough to start precipitation of its solids. This is not an instantaneous process, but a gradual one; and it continues after the water has reached the boiler.

Of course, the efficiency of mechanical purifiers, depending on heat, is proportional to the length of time during which the water is subjected to the heating process. In practice, the water is never thoroughly purified in exhaust or live steam purifiers, because the heater is usually so small that the water passes through it in too short a time to complete the precipitating process. Sulphate of lime is said to be insoluble at temperatures above 300 degrees. This is true provided there is a certain amount of it in the water. Analyses of the water from the blow-off valves of boilers show that the sulphate of lime in solution is as high as 25 grains per gallon, even when the temperature is far above 300 degrees. From this it is evident that it is due to concentration as well as heat that the sulphate of lime precipitates in the boilers, forming scale. Concentration does not take place either in exhaust or live steam heaters, and even if exhaust and live steam heaters did accomplish all that is claimed for them by their makers, they are merely devices for the prevention of scale in the boilers by forming the scale in the heaters themselves, which means that, in place of cleaning simply the boilers, both heaters and boilers have to be cleaned. Neither type of heater is of value for the removal of any of the free acids, such as sulphuric or of such substances as magnesium chloride.

Innumerable other mechanical devices have been tried to overcome this trouble, such as skimmers, surface blow-off valves, etc. Notwithstanding all these contrivances, the scale

continued to form on the plates and the tubes of the boilers. Another method is to apply to the heater water in the boiler a remedy which would keep the scale from hardening.

We now come to the subject of boiler compounds. Mixtures known as boiler compounds have been used for years. The chemistry of boiler compounds is correct, and the subject is thoroughly understood. They are generally composed of soda in combination with some organic acid such as tannic, acetic, etc. All of these acids are said to corrode the metal and to be positively injurious to the boiler.

Almost everything, at one time or another, has been put into the boiler to keep the scale soft, such as shavings, oak bark and tea, for the tannic acid they contain; distillery slops and vinegar, on account of the acetic acid; potatoes and corn, for their starch; leather, slippery elm and manure, for their gelatinous matter; molasses and sugar, because of the saccharates of lime formed. Innumerable other substances have been used, without judgment or reason, as for instance the following, taken from the patent records: Parched ground coffee; extract of logwood; blood meal and salt; all thoroughly mixed with water and substantially as described, and for the purpose set forth.

From the chemical standpoint, the most efficient compounds are tri-sodium phosphate and fluoride of sodium. With these, when the water is heated, both the carbonates and sulphates of lime and magnesia are precipitated as phosphates or fluorides, which do not harden on the tubes and shell. The principle objection, however, is the cost of using them in quantities sufficient to remove enough of the scale-forming matter to be of benefit. They are expensive, first, because the chemical equivalent of these compounds makes it necessary to use one lb. of tri-sodium phosphate to precipitate 9/10 of a pound of carbonate of lime, or .77 of carbonate of magnesia. One pound of flouride of sodium is required to precipitate 1.19 lbs. of lime carbonates, or 1.6 lbs. of lime sulphates, and its cost at the present writing is about two and a half times that of tri-sodium phosphate. There is, however, not the same degree of economy obtained by the introduction of any foreign

substances into the boiler which can be obtained by the use of feed water, purified before entering the boilers, because coal, and therefore heat, is required to keep the temperature of this muddy, insoluble mass of combined mud and scale to the temperature of your water. Furthermore, this foreign matter absorbs an astonishing amount of heat. It is for this reason that sea water boils at a higher temperature than fresh water, and molasses at a higher temperature than either.

A remedy, to be of benefit, must be applied in the proper manner, at a seasonable time, and at the right place. Simply because a substance will, when put into hard water, precipitate lime and magnesia is no reason why this substance should be put into a boiler. Quite the contrary. Heat, without chemicals, causes precipitation in a boiler, and that is just the thing which is not desired. A steam boiler is a still of high efficiency, and not a chemical retort.

The methods described above for the purification of water, either before entering, or while in the boiler, have proved unsatisfactory and expensive, and are at best only partially successful.

We now come to the question of water softening and purification before entering the heaters, economizers or boilers. The chemistry of the subject is extremely simple. We will first consider the substances available for this purpose, their efficiency and economy. The following table gives the quantities of the various substances required to precipitate one pound of carbonate of lime and one pound of sulphate of lime, and the cost of so doing. These figures are based on the present market price of the chemicals.

	.56 lb. lime at ¼c per lb.	.14c
or	2.18 lb. tri-sodium phosphate at 4c lb.	8.72c
or	.8 lb. caustic soda at 3c lb.	2.4 c
or	3.15 lb. barium hydrate at 3c lb.	9.45c
or	11.92 lb. tannin extract, 27% at 2¾c lb.	32.78c
or	2.28 lb. sugar at 5c lb.	11.40c

For the renewal of the sulphates and chlorides 1 lb. of sulphate of lime requires for its precipitation:

.85 lb.	soda ash at 1c lb	.85c
or 1.53 lb.	barium chloride at 2c lb	3.06c
or 8.76 lb.	tannin extract, 27% at 2¾c lb	24.09c
or 1.68 lb.	sugar at 5c lb	8.40c
or 1.6 lb.	tri-sodium phosphate at 4c lb	6.40c

An examination of the above table shows conclusively that lime and soda ash are the most efficient and decidedly the cheapest chemicals that can be used for this purpose.

By means, then, of the chemicals selected on account of their low cost, the small amount required as compared with other chemicals, and the fact that after the chemical reaction has taken place, no deleterious substances are left in solution, this stands a positive fact that lime and soda are the ideal substances for use for the purification of all ordinary water supplies, so as to render them fit for boiler use and to prevent the accumulation of scale in heaters and boilers.

If it is desired to remove the lime, magnesia or iron from the water, the first step is to find a way to convert them into an insoluble condition. These mineral impurities are held in solution by the acids combined with them, such as carbonic, sulphuric, and hydrochloric. Carbonates of lime, magnesia, and iron can be made insoluble by removing from the water the free or loosely combined carbonic acid, by means of caustic lime (Clarke process), and the sulphates and chlorides of lime and magnesia by the use of carbonate of soda (soda ash), because the sulphuric acid or hydrochloric acid has a stronger affinity for soda than for the weaker bases. By the addition, therefore, of these two reagents, in the proper proportions, to the hard water, a chemical reaction takes place followed by the precipitation of the lime, magnesia, and iron. In a properly constructed apparatus these impurities can be removed from the water, and at the same time the mud and bacteria are mechanically removed, and the organic matter materially reduced.

When waters contain only a small amount of free acid, the treatment used is the lime and soda ash, the same as in other cases; but when the waters run high in sulphuric acid (as for instance the Yough River, or mine waters), we employ another treatment, using Witherite for the removal of the

acid; and whatever sulphates will combine with it, are precipitated. The disadvantage, however, in using this substance is that it is insoluble, and this makes its use, in anything but an intermittent system, practically impossible.

The softening and purification of water is an exact process, because an exact amount of chemicals is used to remove a known quantity and character of the impurities which the water contains. The following is a table showing the amount of impurities removed from water by the chemicals usually used:

1 lb. Caustic Lime 98% Ca.O.	Price per lb.	Calcium Carbonate.	Magnesium Carbonate.
Caustic lime, 98% Ca.O.....	1/4 to 1/3	1.78	1.50
Soda ash.....	.88 to 1.15		
	Calcium Sulphate.	Magnesium Sulphate.	
Caustic lime, 98% Ca.O.....			
Soda ash.....	1.28	1.15	
	Calcium Chloride.	Magnesium Chloride.	
Caustic lime, 98% Ca.O.....			
Soda ash.....	1.04	.90	

It might be interesting, at this point, to give some idea of foreign matter brought by a water into a steam boiler, and to one who has never figured this out the amount is astonishing. Take, for instance, a 500 H. P. plant evaporating 30 lbs. of water per horse power, or 15,000 lbs. per hour, equal to about 18,000 gallons per day.

Grs. per U. S. Gal.	1 Day.	30 Days.	365 Days.
7	18 lb.	540 lb.	3.285 T.
14	36 lb.	1080 lb.	6.57 T.
21	54 lb.	1620 lb.	9.855 T.
28	72 lb.	2160 lb.	13.14 T.

There is some objection to the use of soda ash directly in the boilers, because it has a tendency to make the water foam; but there is a great difference between using soda ash in a softening plant and using it directly in the boilers. In a properly designed water purifying plant the carbonic acid is all absorbed first, and the soda ash does not go into the boilers

as a carbonate or bicarbonate, but always as a sulphate or chloride, having decomposed the sulphate or chloride of lime and magnesia. Under certain conditions the same results take place in boilers. For instance, if a raw water contains no carbonic acid, or carbonates, and if the soda ash is used directly in the boiler, a decomposition takes place at once, and the soda unites with the sulphuric and hydrochloric acid, and the carbonic acid of the sodium carbonic unite with the calcium and magnesia, precipitating them as sludge. No foaming due to sodium carbonate takes place under these conditions. But if raw feed water does contain carbonic acid or carbonates, and the sodium carbonate is used directly in the boilers, then it first absorbs the free carbonic acid, which holds the carbonates in solution, and becomes a bicarbonate of soda. Heat drives this extra carbonic acid off, and it is this decomposition of bicarbonate of soda which is one of the causes of foaming. This is aggravated if there is any grease or oil carried over from the feed water heaters to the boilers.

The concentration of sodium salts, other than carbonates, will foam, but there is no good reason why there should be a concentrated solution when there is a good blow-off cock on the boilers, and an intelligent engineer to use it. There are other causes of foaming, such as organic matter when surface water is used for feeding boilers.

Sodium and potassium cannot be extracted from water by chemical means, although it is sometimes claimed by eager salesmen that all potassium and sodium salts can be removed or precipitated from a raw water by their apparatus, or by the chemical reagents used by them. It is absolutely impossible to remove from water, by sedimentation or filtration, any impurities, unless they can first be converted into a state of suspension, either by heat or chemical treatment. All sodium and potassium salts, whether sulphate, chloride nitrate, carbonic, phosphate, or fluoride, etc., are soluble in water under the temperatures in steam boilers. None of these can be precipitated, either by heat or chemical treatment, and therefore none can be removed in any type of water softening and purifying apparatus.

There is but one method, and that is distillation; but that is what a steam boiler does when it makes steam. It is true that alkaline salts can be decomposed by chemical treatment; but no benefit is derived, as the alkaline base merely changes its acid radical to a new salt, which is still soluble in water.

The process of softening and purifying water is based upon the exact quantity and chemical character of the impurities in the water. It is a method based upon an accurate chemical knowledge, and does not require the imagination of any man to prove its efficiency.

The Porter-Clarke process of precipitating carbonates of lime and magnesia by means of caustic lime, and the sulphates and chlorides of lime and magnesia by the soda ash treatment, makes it possible to get a clear feed water low enough in scale forming substances to fulfill all requirements. True water softening is an exact process. By this is meant that the exact amount of lime must be put into the water to remove all the carbonates of lime and magnesia present, and the exact amount of soda ash to decompose all the sulphates and chlorides of lime and magnesia, no more and no less. If it is desired to run at the lowest cost of operation the apparatus must be so simple that any man, who has no knowledge of chemistry, can operate it, and of whom nothing but the mechanical work is required. The apparatus designed to accomplish this may be divided into two classes: the intermittent, or settling tank system; and the continuous system. The apparatus designed for the continuous process consists usually of a settling tank, wherein the water, after the addition of the solutions of lime and soda, is made to flow through separate spaces between series of intercepting plates, in order to effect the mixture of these reagents with the water. It is then passed to the bottom of the tank through a pipe and finally rises again nearly to the top, where it overflows in a continuous stream. These conditions are varied in every possible shape and manner, and give rise to the different systems.

A properly designed continuous system is one in which the lime is fed into it as a saturated solution proportional to the flow of water; the lime treatment completed before the

soda ash is introduced so that it can be determined whether the lime treatment is correct or not; the soda then introduced in proper amount; thorough mixing of water with chemicals, either mechanically or otherwise. The water should then be given ample time for settling and clarification and finally passed through a properly designed filter for removal of the light floating matter.

This system can be used with good results under the following conditions: First, Where the quantity of water required is uniform, or where a clear well is used to take care of the variations in the amount of water needed. Second, Where the water is uniform in character. Third, Where small floor space is available. Fourth, Where it is impossible to obtain sufficient water to furnish the quantity of water required by an intermittent system in a limited period of time. Fifth, Where very large quantities of water are required, the continuous system is the best on account of the reduced floor space required, and because the system is large enough to warrant the attention of a competent man.

The intermittent system consists of two or more settling tanks, provided with mechanical stirring devices, in order to thoroughly mix the lime and soda with the water in one tank, after which the water is allowed to settle while the water in the other is being treated or drawn from it.

In this system the water can be softened and purified with accuracy and uniformity.

The principal objection to this system is the ground room it occupies, and the quantity of water which must be supplied to it in a comparatively short time, to allow for treatment and settling. The necessity for using very large tanks has in a measure been overcome by using a filter to mechanically remove the floating sludge which does not completely settle in the time allowed in the tanks. This plan is not in any sense an obsolete one, for plants are being installed at the present time in this country among the largest manufacturing concerns. To some the settling tank plan may seem crude in comparison with the more elaborate plants working upon the continuous process.

Among the many advantages of the intermittent settling tank system are:

First. The absence of automatic chemical feeds.

Second. It can be operated by the engineer or his assistant without interfering with their regular work.

Third. A constant quantity of raw water is collected to be treated with a uniform amount of chemical reagents. With this plant an excess or insufficiency of chemicals is avoided and therefore a uniform character of the purified water is furnished. While the simplicity of the apparatus enables an unskilled workman to obtain as good results from it as an expert chemist.

Fourth. The chemical stirring results in the agitation of the raw water with the chemicals, and thus insures an intimate mixture and very materially hastens and soon completes the chemical reaction.

Fifth. The sludge of previous purification, which has settled to the bottom of the tanks, is mixed with the water by the action of the mechanical stirring devices. This insoluble matter moving in the water gathers together with the new finely divided precipitate of lime and magnesia aids chemical reaction, and assists the chemicals in clarifying the water.

Sixth. The sludge collected in the settling tanks relieves the filter bed so that the filter can be run from five to six times as long without cleaning as would be the case were the sludge all intercepted by the filters.

Seventh. Inasmuch as the settling tanks do not usually require washing or emptying oftener than once a week, the amount of wash water required is a very small percentage of the total amount purified.

Eighth. The water can stand for some time in order to get complete chemical reaction between the soluble impurities of the water and the chemicals added. Every chemist understands that no chemical reaction is instantaneous. If the lime and magnesia are not completely removed in the purifying apparatus, they are sure to precipitate in the piping, heaters and boilers.

Ninth. The perfect quiet of the water gives an opportunity for complete settling and renders unfiltered water clearer than that from any other apparatus not using filters or from exhaust steam heaters in which crude filters are employed.

Tenth. The operation of this apparatus is the method followed by the chemist in the laboratory, but on a larger scale, and with minor modifications to suit the conditions.

Eleventh. The arrangement of two settling tanks permits an accurate daily record to be kept of the amount of water evaporated in the boilers. This feature will be appreciated by careful managers of large steam plants who have a regard for a coal pile.

Two tanks are usually used. These tanks are filled alternately. The chemical reagents are mixed in a small tank placed upon the top of the settling tanks, and are washed into the water while the tank is filling. The mechanical stirring devices, which consist of paddles revolved by suitable gearing and operated by power, mix the hard water and the reagents together, at the same time, stirring up the sludge of previous purification from the bottom. This floats in the water and hastens the chemical reaction, and causes the new finely divided precipitate to gather into large floculent or woolly flakes, enabling it to settle quickly as soon as the water stops moving.

The paddle-stirring device is the simplest and cheapest on the market. With reasonable care it cannot get out of order. It does not have to be cleaned to be kept in working order. Steam has been tried and finally abandoned, on account of the quantity required. Air, in most waters, will not do, for it is almost impossible to find air which does not contain some carbonic acid. This is just what is to be removed by the lime treatment, and the success of any purifying plant depends on the successful removal of the free or loosely combined carbonic acid, or in other words on a proper treatment with lime. There is also a tendency of throwing back into solutions some of the carbonates, due to the dissolved carbonic acid from the air used for stirring.

The paddle-stirring device can be driven by a small engine, and only in extremely large plants does it require over three horse power.

The softened water is taken out of the tank by means of a hinged floating outlet pipe, arranged to rise and fall with the level of the water, so that the clearest water is drawn from the top of the tank. This method is preferable, because the water from the top carries the least amount of floating lime sludge into the filter beds; and in this way the filters can be run the longest possible time without having to be cleaned, the time varying from five to fourteen days. Naturally, the connections for filling the tanks, and also to wash out the sludge, are placed in the bottom. The washing of the settling tanks is necessary only when the sludge collects to so large an amount as to interfere with the stirring device. A pressure filter can be used in connection with these plants, the water flowing from the treating tanks to the boiler feed pumps, and then being pumped through the filter into the heater and on into the boilers. Or, if an open heater is used, the water from the treating tanks flows into the heater and is pumped from the heater through the filter into the boilers. The water thus purified will not foam, provided the blow-off cock is used properly to prevent the concentration of those impurities which cannot be removed by any purifying system or apparatus.

The above process will render the most turbid waters clear, because the large amount of sediment contained in some waters (which is found so hard to filter by the ordinary continuous process plant) is, in this apparatus, the means by which the water is clarified. That is, the mud or sludge assists precipitation, and helps to remove that of the new raw water which at the same time does not deposit on the filter bed, and thus necessitate frequent cleaning. Properly softened and purified water will not only prevent the formation of new scale, but will bring about the removal of the old scale, based on the fact that the impurities in the water which form scale, because of heat, by the continual evaporation of the water reaches a point where it can no longer hold more

foreign matter in solution. Therefore, the unequal expansion of the metal, and the non-conducting scale kept cool by the purified water, tends to loosen and crack off the old scale. The latter then floats through the tubes and shell (there being no new deposit of lime and magnesia to further cement it), at least that has been the result in the different places where we have installed water purifying plants. Of course, the removal of this old scale, when using only purified water for this purpose, requires longer time, but it is accomplished with less danger to the boiler, because no inquiry can come to the metal from the water thus purified. There is also no danger of burning the sheets by the accumulation of scale, which would result from the introduction of some acids or other material into the water.

The removal of scale necessitates frequent shut-downs, the cost of labor and the expense of repairs, aside from the loss of energy of fuel, due to the non-conducting property of scale. This depends somewhat, of course, upon the chemical composition of the scale.

All sorts of tables, and some of them from good authority, are circulated by manufacturers of so-called scale preventatives; and while they are probably very much exaggerated, and possibly unreliable still it has been proved, by practical experiments, that metal covered by non-conducting material must be heated to a much higher temperature in order to boil water contained therein, than if the metal is clean.

There can, therefore, be no possible doubt that a scaled boiler requires the use of more heat to generate a given amount of steam than one which is clean. Of course, the results vary with the different types of boilers, and to such an extent that no accurate table can be prepared to prove the exact amount of additional fuel necessary for the generation of a pound of steam under these varying conditions.

The purification of water before entering the boiler results in a saving in the following ways:

First. It saves the labor of cleaning the boilers and heaters, piping, etc. Saves the cost of repairs and saves fuel. In the latter instance the reasons are evident.

Second. The heater is kept clean and the feed water can be raised to a higher temperature.

Third. Coal is not used to heat the impurities in the water or the quantity of compound which you put in to prevent scale formation.

Fourth. The heat is all used in the boilers to make steam and make it quickly and well from the purified water.

Fifth. Purified water keeps the metal of the boiler free from scale and loosens up the old scale in parts inaccessible to the man who enters to clean the boiler, and a higher degree of evaporation is possible than through any other means.

Sixth. Purifying the water is the only way which admits of getting full benefit of the high evaporating power in water tube boilers and furnaces in which water tubes are used for grate bars, because there is no danger of the tubes becoming filled with scale and then burning off or leaking.

Let us see what it looks like in dollars and cents for a year's run. The following statement was taken from the books of a manufacturing establishment having a 2,000 H. P. plant, for one year preceding; also for the second year after the installation of a water softening system. Unfortunately, no record of the fuel saved could be obtained, as it was not considered of sufficient importance by these people, on account of the coal being taken from their own mine. I have, however, assumed that it will require one ton of coal for heating a cold boiler to steam and the evaporation increased from 10 lbs. of water per horse power per hour, per pound of coal to 10.1 lbs.

Cost of Operation without Water-Softening Plant.

Cleaning 8 250 H. P. boilers, each once in two weeks, 208 cleanings per year, at $20.....	$ 4,160.00	
208 tons coal, at $1.00 per ton, to get steam on boilers cooled by cleaning.....	208.00	
Yearly extra repairs on eight boilers due to bad water.....	150.00	
Boiler compound for 8 boilers, per year.....	300.00	
		$4,818.00

Cost of Operating with Water-Softening Plant.

Yearly cost of chemical reagents to treat 60,000 lbs. of water per hour, at 7/8c per 1,000 gals..	$ 551.88	
Yearly interest 8% and depreciation 10% on $4,500	720.00	
Yearly labor of operating plant, at $1.00 per day.	365.00	
Washing 8 250 H. P. boilers, each once every 3 months, or 32 washings per year, at $8.....	256.00	
32 tons coal at $1.00 per ton, to get steam on boilers cooled by washing.....	32.00	
		$1,924.88
Saving by using softened water about 63% on $4,500		2,893.08
2,000 H. P. boilers evaporate 60,000 lbs. of water per hour, or 1,440,000 gallons of water per 24 hours. Evaporation without prifier at 10 to 1 equals 144,000 gallons; 72 tons of coal per 24 hours, at $1.00 per ton, a yearly cost of.....	26,285.00	
If evaporation were increased to 10.10 lbs. of water per pound of coal due to having boilers free from scale 1,440,000 lbs. of water should be evaporated each 24 hours with 71.28 tons of coal at $1.00 per ton, a yearly cost of.....	26,017.20	
		$ 267.80
Estimated saving over 70% on $4,500 investment.		3,160.88

We find from our records, taken from over 300 plants, that the saving due to the use of a purifying system varies from 25% to 150% on the investment, depending on the quality of the water supply and other conditions; the average being about 50%. So it is evident that it would be hard to find a better investment or one productive of better results along the lines of economy and safety.

I thank you for your kind attention.

DISCUSSION.

CHAIRMAN—Some time ago Mr. Handy read a paper before the regular meeting of the Engineers' Society. Unfortunately the time for discussion was very short, but I see Mr. Handy is here to-night; perhaps he could say something in the way of water softening to us.

MR. HANDY—Mr. Chairman, the subject of water softening is one that has interested me very much for a considerable period. I have been very much interested to-night in Mr. Greth's paper,

and I hope it is fully appreciated, because I have found that the preparation of a paper of this kind involves a great deal of hard labor.

I can add several instances of material saving by water softening to the one given in Mr. Greth's paper, and I think the one cited is by no means exceptional. The only wonder is that, as those cases are becoming more and more known, the progress of water softening is not more rapid than it is. I have one case in mind, that of an ice factory in Chicago, where they had nine one hundred horse power boilers and used Lake Michigan water, which is not any harder than the Monongahela river water used by so many plants in this vicinity. In the course of a year by the use of a softening plant they saved $780.00 on cost of cleaning boilers, because the necessity for cleaning was so much reduced, and there was no scale to be removed. They saved also fifteen per cent. of the annual fuel bill, which had amounted to over twenty thousand dollars. The investment for the softening plant was $4,900. The saving on fuel and boiler cleaning alone paid for the plant in one year. After that the softening plant was a steady dividend producer. The coal saving was certified to by an audit company. While large savings come from the installation of the softening plants, any move in the direction of softening is sure to be accompanied by some saving.

A few years ago it was quite the fashion among railroads to use soda ash as a means of purifying the water in the locomotive boilers. The soda ash was put in the tank with the water, in amount roughly proportional to the water that was to be used on the trip. Crude as that was, it kept the scale from accumulating to a considerable extent. The C., M. & St. P. Ry. was, perhaps, the principal advocate of that method of preparing water. It was reported that they saved $75,000 per year on boiler repairs, just by the use of soda ash. The Union Pacific Railroad made quite extensive experiments with tri-sodium phosphate in much the same manner, and while the improvement in service was great in many ways, the cost of the chemical was so much higher than soda ash that they were not able to continue the treatment. There are over 275 softening plants in the United States, purifying about 70,000,000 gallons of water per day. The users include

railroads, iron and steel works, iron foundries, electric light plants, street railways, etc.

A very good instance of saving by softening of water not harder than that of Lake Michigan is as follows: The Nichols Chemical Company of New York in one year obtained the following benefits: 2,500 horse power plant; fuel saving, 20%; labor saving, 25%; boiler repairs reduced, 75%. They were able to get along with about two-thirds to three-fourths the number of boilers which was necessary before. The chemical cost was only $2.46 per day, and the time of the man attending to the machine amounted to about two hours daily.

Mr. Greth has given some points of differences between the continuous and the intermittent systems of water softening, and it might be well to take up that feature for a moment, because there is really no question as to the benefit of water softening, and the only question is as to the means you shall use when you come to the point of deciding on the method of softening. As far as the matter of price goes, the intermittent systems outlined cost him three-fourths to four-fifths as much as the continuous type. Then the consideration of the engineering features comes in. Comparing results on waters of similar character, we find good work done by both types of machine. I have a table of analyses which I will not read to you, because the figures are not very intelligible when read.

1. The *continuous* plants reduce the lime to as low a figure as do the intermittent types.

2. *Comparative output* of plants. They have a We Fu Go plant at Lorain, O., consisting of four one hundred thousand gallon tanks. The output is 50,000 gallons of softened water per hour. The ground space is 3,200 square feet, approximately. The tank capacity of the Kennictt (continuous) softening plant at McKees Rocks, for an output of 60,000 gallons per hour is approximately 250,000 gallons, and the ground space that is required is about one-fourth of that needed by the We Fu Go plant.

It will be noticed that while the We Fu Go plant occupied about four times the area, yet its output was just half that of the Kennictt. The ratio of the tank capacity to hourly output in the

Clark process is 29 to 1, in the intermittent 8 to 1, and in the modern continuous system 4 to 1.

3. *Repair and operation,* taking for comparison again, the Lorain plant and the McKees Rocks plant. At the Lorain plant there is the work required to run the engines, etc. Twenty-four large valves have to be opened and closed daily; 24 batches of chemicals to prepare; excess sludge to be removed from four tanks; two filters to clean. McKees Rocks plant: Boy required to take care of plant; no engine or shafting; one valve is opened four times a day to remove the lime; four batches of chemicals.

4. *Power for operation.* Lorain: Engine required; to run sturer and rakes in four thirty-foot tanks, and two sixteen-foot filters. McKees Rocks: All work is done by the power of the water entering the softening plant; the use of the water for power makes the plant independent of outside steam power. This is a weakness of We Fu Go plant.

5. *Durability and maintenance.* In most cases the intermittent plants are of wooden construction, while the continuous ones are of steel; the depreciation of steel plants would be next to nothing.

6. *The chemical regulation* of intermittent plants is usually checked by what I consider very imperfect chemical tests.

Summary: Comparing continuous and intermittent softening plants properly designed and well taken care of, it requires a larger plant and involves greater expense for the intermittent system. Competent supervision is required for both kinds of softeners.

CHAIRMAN—Those two instances are somewhat of a guide. Now perhaps it could be brought down to a statement. Say it required so many feet per hundred horse power, or something like that, and this would enable the manufacturer to determine whether he should have either continuous or intermittent system; whether he would have room, etc.

MR. GRETH—A comparison of the Lorain steel plant with a plant which is being turned out now is not altogether fair. The Lorain Company's plant is designed on an eight-hour basis, and very few modern intermittent systems are designed on that basis.

Mr. Handy—But the ratio of the capacity of the two systems is about as four to one. The changes we have in the waters of the local rivers, and which we have to take care of in the intermittent systems by frequent tests, would indicate that similar tests are necessary in the continuous system, and I would like to know what those tests are. In regard to the fact that the steel tanks have a longer life than the wooden, I also would like to have some information. In several places where these have been put in it was found that the steel tanks did not have a very long life and gave considerable trouble. We have had one or two plants of the intermittent type in operation, and one that has a continuous system. It has given very good satisfaction, especially in the care of the boilers and the repairs.

In regard to the tests that are made in controlling the continuous plants, I suppose there is no good reason why they should not be used in the intermittent systems as well, but they are not. The soap test and the hardness test are about the only ones that are carried out by the men at the plant. The soap test gives the total hardness of the water, which is a means of recognizing any change which takes place in the treatment of the water.

As to the matter of durability of steel tanks, when they are full of an alkaline liquid, such as they would be in water softening, it seems to me there should be no question of that. The parts above the water, if they are alternately exposed to water and air, would be corroded. If the gentleman knows of a case where, in spite of being continuously immersed in alkaline water, the steel does corrode, it certainly will have to be investigated.

Mr. Greth—We have been using, for sometime, both steel and wood construction, both in the intermittent and continuous systems, and we find that the wood tank system gives the best service with less trouble. We have also found that sludge will adhere to the side of the steel tank, while it won't adhere to the sides of the wooden tank; at least this was our experience at the Lorain Steel Company. One of the objections which the general manager of that company made, and which induced him in the second system he installed to put in wooden tanks, was that the

sludge adhered to the sides of the steel tanks and required time and labor for cleaning them.

In reference to the tests we employ, would state that it is only in such instances where we cannot get men of sufficient intelligence to do no more than apply color tests, and sometimes not even those, that we employ color tests. Usually we employ a lime water for the insufficiency and titration to determine excess of the lime treatment, but our experience has been that only in rare cases are men of sufficient intelligence furnished to make any tests which require such careful manipulation as the soap test.

MR. FLANIGAN—I would like to ask Mr. Greth how they construct the wooden tanks for this continuous system. It is under extreme high pressure at times. In case they had two hundred pounds pressure, what is the practice in constructing them?

MR. GRETH—The gentleman is undoubtedly talking about the pressure system, which we manufacture especially for plants where very little floor space is available, in which case we do not use anything but the steel tanks.

CHAIRMAN—What pressure would the ordinary tank be subjected to?

MR. GRETH—Simply the weight of the water it contains.

MR. FLINT—I would like to know whether it is possible in a general way to state the first cost of installation, per thousand gallons, of the intermittent and the continuous systems?

MR. GRETH—That is rather a difficult question. I do not believe I have ever computed figures on that basis.

CHAIRMAN—Is Mr. Johnson here to-night? If so, I would like to have a few words from him.

MR. JOHNSON—I think that this question has been very thoroughly discussed. It is an undisputed fact that the small substances should be removed from the water before it has gone into the boiler, but after it is there once, the precipitation by heat alone is the main cause of scale forming.

MR. FLANIGAN—Mr. Chairman, I believe a prominent item in connection with the intermittent system is the filter, and I do not think Mr. Greth touched on that sufficiently.

MR. GRETH—I did not expect to discuss the subject of filtration as applied to water purification. We have found, through

quite a number of years of experiment, and not only our own experiments but also those of companies which we have absorbed, that to successfully purify water it is absolutely necessary to filter it after the chemical operations have taken place, and the only type of filter we have found to give satisfactory results is the regular mechanical gravity or pressure filter. All the filters which we employ are fitted with a bed of strainers in the bottom, on top of which rests the graded quartz and filter sand, and on top of the filter bed we use a net-work of piping, slotted on the top, to take off the accumulated sludge, etc., from the filter bed. We formerly used a mechanical stirring device, but found it was not efficient in carrying off all the sludge from all parts of the filter bed, so we did away with the mechanical stirring device, and with the strainers which we now use we have been able to get excellent results. This strainer is a cylinder, the barrel of which is made up of round brass rods. These strainers are placed at right angles to each other, so as to wash every part of the filter bed. In the washing process the water brings about a kind of boiling of the sand, which lifts the mud and sludge high enough to wash it into the slotted pipes. We use this type of filter on all our intermittent and continuous systems. We formerly used an excelsior filter on our continuous systems. This did not fill the bill, so we cut that out, and are now using the regular mechanical gravity filter in every case. In our pressure plants, of course, we use the pressure filter. In the gravity plants we often use a pressure filter where the conditions are such that a pressure filter will meet the requirements better on account of reduced floor space.

MR. FLANIGAN—I think I can understand Mr. Greth to imply that all that is necessary in washing those filters is to reverse the flow of water. Is that correct?

MR. GRETH—Referring to the washing of the filters, the water is introduced at the bottom and washed up through the bed. This lifts the sludge, etc., as explained before, into the slotted pipe work, which is then carried to the sewer.

Of course, in the operation of the filter the water goes into the top of the filter and out at the bottom.

MR. HANDY—As to excelsior filters, I can say that I was very skeptical about their having any merits whatever, and I know now

that they have their limitations. In an apparatus that is so designed that the clarification is quite perfect an excelsior filter about one foot in thickness, and properly packed, will remove the suspended particles.

MR. GRETH—Speaking of the continuous systems, I recently saw a plant installed by a company which we bought out sometime ago. The plant was designed for a capacity of 3,000 horse power, or about 12,000 gallons per hour. The capacity of the various tanks in connection with the system were large enough to hold the water for about five hours. The last tank, the settling tank, was of sufficient size to hold the water for three hours, allowing that time for settling. The entire area of this tank was used as a filter, and was about 22′ in diameter. Excelsior was used as a filtering medium, and was placed over this entire area about 2′ thick, and the results obtained at this plant showed the water still to contain considerable fine sludge. This may have been due to improper treatment of the water, but our experience has been, especially in the continuous type of apparatus, where we had a varying water supply, that it is difficult to have a man keep his treatment just right, and it is necessary to supply some means to positively keep out the sludge, and we have not been able to do it with the excelsior filters. Possibly others have been more successful.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and forty-second regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa. Tuesday evening, February 16th, 1904, at 8:25 p. m. President J. M. Camp in the chair and thirty-six (36) members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications and present same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
AMBROSE E. ANDERSON,	Attorney at Law and engaged in Scientific and Mechanical pursuits pertaining to Engineering, 321 Frick Building, Pittsburg, Pa.	W. G. Wilkins, W. M. Judd, J. F. Kuntz.
WARREN I. BICKFORD,	Electrical Engineer With Iron City Engineering Co., Frick Building, Pittsburg, Pa., h., 4953 Centre Avenue, Pittsburg, Pa.	W. B. Hough, T. E. Doyle, V. F. Holmes.
ARTHUR L. BOBBS,	Employed by Chas. Worthington, C.E. Farmers Bank Building, Pittsburg, Pa., h., 365 Carolina Street, Pittsburg, Pa.	Chas. Worthington F. V. McMullin, W. H. Baltzell.
HAROLD P. CHILDS,	- Manager - Pittsburg Office, Power & Mining Machine Co., 823 Farmers Bank Building, Pittsburg, Pa.	W. B. Hough, V. F. Holmes, C. W. Ridinger.
THOS. A. COLLISON,	- Estimator - With Standard Steel Car Co., Pittsburg, Pa., h., 310 West North Avenue, Allegheny, Pa.	E. T. Parker, Frank Irwin, A. Stucki.
RAYMOND H. DANFORTH,	Draftsman Westinghouse Electric & Mfg. Co., East Pittsburg, Pa., h., 926 South Avenue, Wilkinsburg, Pa.	C. E. Skinner, M. A. Tenney, M. Knowles

THOS. HANNAH, Member of the Firm
Struthers & Honnah, Architects, Pittsburg, Pa.,
h., 433 Pacific Avenue, Pittsburg, Pa.
{J. B. Hardie, H. J. Lewis, C. W. Ridinger.

HERMAN A. HEUPEL, Master Mechanic
Macbeth Evans Glass Co.,
h., Charleroi, Pa.
{S. A. Stupakoff, S. E. Diescher, Otto Rothenstein.

JOHN S. HOLLIDAY, - Draftsman -
With The American Foundry & Construction Co.,
h., 1202 Franklin Avenue, Wilkinsburg, Pa.
{C. H. Israel, W. L. Klingelhofer, C. T. Klingelhofer.

PHILIP H. JANNEY, With The New Process Lubricating Co.
h., 4935 Center Avenue, Pittsburg, Pa.
{W. B. Hough, Walter Schmidt, V. F. Holmes.

STONE KEIL, - Mechanical Engineer -
With Bair & Gazzam Mfg. Co., Pittsburg, Pa.
h.. 1214 Irwin Avenue, Allegheny, Pa.
{W. H. Smith, J. A. McConnell, H. M. Wilson.

CHAS. M. MEANS, Electrical Engineer
R. & P. Coal & Iron Co.,
h., Punxsutawney, Pa.,
{J. M. Phillips, H. J. Lewis, J. P. Bartholomew.

WM. A. PAGE, - General Salesman -
Pressed Prism Plate Glass Co.,
Morgantown, W. Va.
{F. L. O. Wadsworth, S. M. Kintner, H. W. Fisher.

JAMES W. P TTERSON, Jr., Asst. Engineer
On P. C. & W. R. R., (Wabash),
331 Fourth Avenue, Pittsburg, Pa.
{G. T. Barnsley, M. Knowles, C. W. Ridinger.

V. E. SISSON, - Draftsman -
With Standard Steel Car Co., Frick Building,
Pittsburg, Pa., h., 812 Arch Street, Allegheny, Pa.
{Frank Irwin, E. T. Parker, F. B. Bissell.

W. B. SPELLMIRE, Associated with
The Bullock Electric Mfg. Co.,
1723 Farmers Bank Building, Pittsburg. Pa.
{W. B. Hough, F. V. Holmes, T. E. Doyle.

JESSE A. WHITEMAN, - Assistant -
To the President and General Manager of the R. & P. Coal & Iron Co., and affiliated Coal. Iron and R. R. interests, Punxsutawney, Pa.
{J. M. Phillips, H. J. Lewis, G. P. Bareholomew.

A. W. WYCKOFF, President A. W. Wyckoff Co.
Manufacturers' Agents, Pittsburg, Pa.,
1723 Farmers Bank Building, Pittsburg, Pa.
{W. B. Hough, T. E. Doyle, V. F. Holmes.

Moved that the secretary cast ballot electing the gentleman to membership. Motion seconded and carried.

MR. DIESCHER—Mr. President, I would move that a committee be appointed to draw up resolutions in the memory of the late Selwyn M. Taylor, who was a member of this Society.

Motion seconded and carried.

MR. CAMP—I appointed on this committee, Messrs. George S. Davison, Chairman, H. J. Lewis and W. E. Fohl.

We have a request for a change in our By-Laws. Add to Article 1, Section 2, first sentence, "and if not matriculated within six months the election be cancelled."

Since that was submitted I understand there are several other things needing revision in the By-Laws, and if it is in order I would move that a committee of three be appointed, to revise such things as would be considered necessary and report at an early date.

Motion seconded and carried: Committee, Messrs. S. M. Kintner, Chairman, Bole and Hirsch.

MR. CAMP—We will now have the pleasure of listening to Mr. Alfred J. Diescher on the Smelting of Zinc Ores.

THE SMELTING OF ZINC ORES TO REGAIN SPELTER AND SULPHURIC ACID.

BY MR. A. J. DIESCHER.

Zinc ores are generally found associated with lead ores. To secure the zinc ore it is necessary to separate the lead ore from the association. The lead ore, having a specific gravity of 7.4 while that of zinc ore is about 4, is well separated to a very great degree of exactness, by jigging or concentrating. It is also found associated with other ores as those of iron, silver, copper and gold. But as a rule lead and iron always exist to a greater or less extent in such associations, and have very much to do with the value of the ore for smelting purposes. The iron found is generally sulphide of iron, or pyrites.

The principal sources of ore supply in this country are, in the order of their importance, the Joplin, Missouri, District, taking in the southwestern section of Missouri, the southeastern section of Kansas and a portion of Arkansas; the eastern field, taking in a portion of Pennsylvania and New Jersey, and the western field, taking in Colorado, other western mining states and also British Columbia. Aside from these fields, zinc ores are obtained in various parts of the United States, as in Wisconsin, Southern Illinois, Kentucky, Virginia and other states. While there are small smelting works located in Wisconsin and in Virginia, the amount of ore mined and smelted is not so great as to rank these states as important spelter producing states. Most spelter is produced in Kansas while Illinois ranks second in production.

The ores from the Joplin field are known as Joplin ores and are the best of all, being high in zinc and consequently low in impurities. The ores from the western states are known as Western ores, and are as a rule by-products from gold, silver or lead mines. They carry considerable iron and lead even after concentration and sometimes also carry considerable silver and traces of gold. For a long time they were considered a waste

product and it is during the last few years only that they were smelted for the zinc. Zinc in gold and silver ores, reduces the value of those ores, as in smelting losses of gold and silver are caused by the volatilization of the zinc.

These western ores as a rule are sulphide ores and carry as high as 20 per cent. iron, 8 to 10 per cent. lead and 20 ounces of silver to the ton. Ore passed through magnetic separators is much lower in iron. Lead and iron are the two most important contaminations of zinc ores, and it is upon the amounts of these two metals, as well as upon the zinc contents of the ore, that the value, and also the method and care of working the ores, are based. These contaminations not only affect the quality of the metal produced and the treatment in working the ores, but are very injurious to the furnace retorts, causing greater losses in the reducing process, beside making the physical side of the roasting process more difficult to perform, and making it also more wasteful of fuel. In fact in some types of roasting furnaces, these western ores cannot be worked at all, owing to the physical rather than chemical difficulties occurring, as shall be described later on. Between the lead and the iron in the ores, the iron causes the most trouble owing to the damage to the retorts, as will be referred to later on. For the purpose of overcoming the troubles due to iron, the three principal companies working the western ores have each adopted their own method of treatment. The New Jersey Company have undertaken to eliminate the iron from the ore by magnetic separation. They have met with considerable success in this line. The Cherokee-Lanyon Spelter Company took up the matter of protecting the retorts against the attack of iron by lining the inside of the retorts with a basic lining. They claim to have successfully worked ores containing 19 per cent iron. The Lenyon Zinc Company have adopted still another method of overcoming the trouble in which they have met with a large degree of success. Their way is simply to regulate the temperature of the reducing furnaces to suit these ores, working them at a lower degree of heat than is required for Joplin ores. A combination of these three points should result in a still greater economy.

The western ores being by-products and coming from fields

requiring long hauls on the railroads, must sell at very low prices to compete with the Joplin ores. This is especially true of British Columbia ores, the freight charge on which is alone $11.00 per ton to the Kansas smelters.

The New Jersey ores are a peculiar combination, especially the Franklinite ores, which contain iron sesqui oxide, manganese protoxide and zinc oxide. The iron and the manganese are separated, after calcining by means of magnetic separators, the tailings, containing the zinc oxide, are smelted to recover the spelter or the pigment zinc oxide.

The Joplin ores are highest in zinc contents and are of three classes according to their chemical combinations. The principal and most valuable ore, both on account of the high zinc contents and the economy in smelting, is zinc sulphide, or elende. (Zn S). This is fortunately the most common ore. Beside this class there are zinc carbonate (Zn C 03) and zinc silicate ores (Zn 2SI 04)

Sulphide of zinc, free from foreign matter, consists of by weight approximately 67 per cent. zinc and 33 per cent. sulphur. However, in actual practice ores containing from 58 to 60 per cent. zinc and from 28 to 30 per cent. sulphur are the commercial ores. They are purchased on the assay basis, deduction being made for moisture, lead over 2 per cent and iron over 1 per cent. of the weight of the ore. However, at some works, where sulphuric acid is made as a by-product from the sulphur in the ore, a lower limit for lead is necessary, due principally to the trouble caused by lead in the roasting furnaces.

In the Joplin District the ore is found in pockets or blankets, and not in what is understood by veins. For this reason mining is very uncertain, in fact so much so that none of the smelting companies have ventured very far into it. They prefer buying the ore from the different miners. This makes the ore buying a very large undertaking, and each smelter has an ore buyer in every division or district of the ore fields. The buyers usually contract to buy the ore and deliver it on board cars, on the nearest siding to the mines. The mines are so great in number and so scattered that the railroads do not run sidings to them. This necessitates that the ore be hauled to the cars by team. It is the custom to buy in qauntities at a time large enough to extend over a consid-

erable period. Some works try to keep on hand thirty days' supply of green ore. The ore is bought at the different mines whenever there has accumulatd a sufficient quantity to justify hauling to the railroad cars. This causes considerable trouble in shipping and also in handling the ore upon its receipt at the smelting works. It is a common thing to have ore from five or six different mines in a single box car. They are of different analysis as to moisture, iron, lead and zinc, and must be kept separated from each other during transportation. When the ores arrive at the different works samples of each grade are taken, as well as a record of the amount of each grade so that the smelter can arrive at a settlement with the miner for the ore, and also that the ore can be stored in different bins according to the system of grading at the respective works. The system of grading will not be taken up at this point as it will be considered later on.

Before passing on, from the ores, it is well to state that the selling prices of the ore is not constant or anywhere near constant. That it fluctuates both with the supply and demand of ore as well as with the selling price of spelter, the selling price of spelter controlling. This latter feature would not be the case were it not that whenever the price of Joplin ore is increased it results in a greater demand for the inferior western ores. The smelters do not desire to work the western ores if they can get a supply of Joplin ores at ordinary prices. The greatest demand for the western ore exists at the time when both the Joplin ores and spelter are commanding high prices. From the standpoint of the smelter western ores are looked upon mainly as a means for keeping down the Joplin market.

Zinc is the pure metal while spelter is the commercial metal containing such impurities as are brought over during the smelting process. Zinc is only obtained by refining spelter. It is used for chemical purposes and also for casting ornamental work, as monuments, statuettes, etc. It is thinner than spelter and runs better in casting. Spelter is rolled into sheets for roofing, stamping and other purposes. It is also used for galvanizing, for electrical purposes, for brass making and in the form of shavings, for the cyanide process of gold and silver extraction.

As sulphide ores are most common the smelting of those ores

shall be given most consideration herein; however, mention shall be made from time to time as to the difference in the process for the smelting of the carbonate and silicate ores.

The first step in smelting the sulphide ores is roasting, whereby the sulphur is driven out of the ore by combustion, both the zinc and the sulphur uniting with oxygen, thereby forming the two products, zinc oxide (Zn o) and sulphurous oxide (S o2).

After the ore is unloaded from the railroad cars and sampled, it is stored according to its grading, at some of the works, while at others it passes through the roasting process without any special grading. As no works will mix western ore with Joplin ore, it follows to begin with, that there are grades of ores according to the fields from where they were obtained. However, Joplin ores have a further grading, that is carried out to a very great extent at some of the works. The Lenyon Zinc Company have as high as ten different grades. Outside of the grading according to the chemical combination in which the zinc is held, it is common to grade according to the percentage of zinc contained in the ore, and also according to the amount of iron carried in the ore. The reason for this latter grading will readily be understood when it is considered that an ore high in iron will roast at a lower temperature than ores that contain less iron. It is a well known matter among smelters that ores very high in zinc content are not the most economical to smelt. The percentage of zinc lost, or in other words the percentage not regained from the ore, is greater in working these high grade ores than it is with the lower grade ores. For this reason the ores are graded according to their zinc content. Outside of the grades due to the above system of grading, there are the sludge ores, which are the fine settlings from the concentrating jig. The carbonate and silicate ores form the other grades due to chemical combination.

Although the ores come from many different mines, and a single carload seldom consists of less than two grades, it is found on averaging the analysis of all ores received during each month, that the average from month to month shows very little variation.

As every grade of ore requires special treatment, as regards temperature in the reducing furnaces, and also that every charge requires a gradual change of temperature during the time of work-

ing it, it is evident that the greatest economy will be attained by keeping as near as possible to one resultant grade of ore, brought about by mixing the proper proportions of the different grades. As a result the men operating the furnaces become skilled in handling the resultant grade and in regulating the temperature to secure the best results from that grade. As it is the custom to allow the men a bonus, for all metal recovered above 35 per cent. of the content of the ore, every effort is made by them to attain the best result.

Preparatory to roasting, it is necessary to drive the moisture out of the ore. For this purpose various methods of drying have been adopted at the different works. After drying, the ore is crushed in crushing rolls, and passed through a revolving screen, of either six or seven meshes to the inch. Finer crushing than this is not advisable for several reasons. The dust losses from finely crushed ores are greater than from coarser crushed ores; it is harder to keep finely crushed ores on the hearth of the roasting furnace, due to the bubbling tendency from the sulphurous gases arrising from the ore, and further that since it is necessary that oxygen be brought into close contact with every particle of the ore to result in successful roasting, the finely crushed ores leave such a small amount of space between the grains that the air can not penetrate between them. This is why the roasting of finely crushed ores is especially difficult. The sludge ores, which are much finer than sand, cannot be roasted alone and are always mixed with coarser ores. Even with this mixture, on examining the roasted ore as it leaves the roasting furnace or kiln, it is always found that the sludge ore comes out in the shape of little balls up to three-sixteenths of an inch in diameter. Fine ores, between the grains of which the air cannot penetrate, have a tendency to cake.

At present the losses in dust passing out of the stack and through the openings of the furnace, amounts to one per cent. of the total amount of ore roasted, at one of the leading works. This does not appear like very much, but in this case it amounts to a daily loss of about $70 worth of ore.

After leaving the screens the ore passes into bins, over the

more modern furnaces, from where it is fed in a constant stream into the furnace.

Zinc sulphide contains one atom of sulphur for each atom of zinc. Pyrites of iron, as are used in the manufacture of sulphuric acid, contain two atoms of sulphur for every atom of iron. The sulphur from the pyrites is more easily burned out then that combined with the zinc. In the case of the zinc sulphide it is necessary to supply heat from some outside source to carry on the roasting process. This heat is furnished either by the combustion of cool, producer gas, or natural gas. To bring the air in close contact with the particles of ore, it is necessary to stir or turn them over frequently. The oftener the ore is turned over the greater the output of roasted ore per square foot of hearth area. As stated before the temperature required to roast varies with each grade of ore, the more pyrites contained in the ore the lower the temperature required to roast it, and also the purer the ore the greater the temperature required to roast it. This temperature p lays an important part, no only regarding the amount of fuel required, but also because it is very destructive on the machinery used to turn over the ore. The amount of ore roasted in twenty-four hours varies from twelve to thirty pounds per square foot of effective hearth area. The ore remains on the hearth about eighteen hours to effect complete roasting. This length of time varies to some extent with the rabbling or turning over of the ore to afford access of the air. At the starting or entering point of the hearth the temperature is at its lowest, gradually increasing toward the discharge end of the furnace, until it reaches its maximum at a point at about two-thirds of the length of the hearth, from whereon it gradually drops to the discharging point. In the furnaces as used at the Lanyon Zinc Works the hearths are 14 feet wide by 150 feet long. At the front end the temperature is about 900 degrees and raises to about 1800 degrees as a maximum at a point 100 feet in, then gradually drops to about 1200 degrees at the discharging end. These temperatures are not held stationary but are constantly regulated to suit the nature of the ore being roasted. The roaster in charge takes samples from different points, throughout the length of the furnace, and upon cracking the grains can tell by the appearance of the fracture, whether the

sulphur is burned out or not. A shining or sparkling point indicates sulphur, and if upon cracking, he can find no shines the roasting is considered complete. However, should he find shines to any extent, the roasting is not considered complete and the necessary increase in temperature is made to produce ore at the discharge that will show no shines.

It is a common thing to roast ore, containing 20 per cent. sulphur, down to $\frac{1}{4}$ to 1 per cent. sulphur and sometimes even less. At most works roasting to one per cent. is considered good practice while at others, $\frac{1}{2}$ of 1 per cent. is demanded. Whatever zinc there remains combined with sulphur in the roasted ore can not be regained in the reducing furnaces and for this reason is practically a dead loss. The importance of roasting to the lowest limit, is readily seen, when it is considered that for every pound of sulphur left in the roasted ore, two pounds of zinc, which are combined with that pan of sulphur, are lost unless the iron in the ore combines with part of that sulphur and liberates some of the zinc. A premium is allowed the roasters for close roasting at some of the works.

In roasting the sulphur takes up two atoms of oxygen forming the gas sulphurous oxide (S 02). The zinc unites with one atom of oxygen forming zinc oxide (Zu 0), which remains in the ore. Some sulphuric oxide (S 03) is also formed, and there is danger under high temperatures of this (S 03) uniting with the (Zn 0) and forming zinc sulphate (Zn S 04). However, in practice there is very little trouble due to this formation; the extra 0 of the (S 03) usually being taken up to form (S 02) or by the zinc forming (Zn 0). During roasting, 60 per cent sulphide ores lose 30 per cent of their weight, if all sulphur is roasted out, and regain 15 per cent. of the original weight from the oxygen taken up by the zinc. This makes the roasted ore weigh about 85 per cent. of the original weight, when it was green ore. Of course the loss in dusting must be deducted in figuring the output in tonnage.

Of the contaminating metals in the ore, lead is the only which causes trouble in the roasting furnaces. This is due to the fact that it has a tendency to deposit or build up on the hearth, and there form an obstruction to the passage of the rabble through the

furnace. In furnaces having a single hearth this is not as serious a matter as it is in muffle furnaces. In the former type where the height of the arch over the hearth is quite high, the depositing of lead is allowed to accumulate and the furnace is closed down once a year for the purpose of changing the bed, thereby removing the accumulation. Should the accumulation at points become troublesome it is chipped off with a bar. In the muffle furnaces where the head room is limited, and made a minimum, such deposits are more troublesome. Such furnaces have the roasting hearths located over the combustion hearths and the heat reaches the roasting hearth through the fire brick floor. Accumulations on the hearth or bed are bad as they interfere with the proper heating of the ore and with the passage of the rabble. For this reason it is the custom to limit the amount of lead, in ores to be roasted in these furnaces, to not over one per cent. of the weight of the ore.

In roasting Joplin as well as Western ores, there is always more or less danger of the ores caking or crusting. In designing the roasting furnaces, special care must be taken to have ample power to draw the rabble through to break up this crust. This trouble occurs to a much greater extent with the western ores than with the Joplin ores, in fact on some furnaces where they changed from Joplin to Western ore it was found necessary to use special sharp pointed rabbles to cut through the crust. This sharp pointed rabble was passed through the furnace once every seven minutes.

In muffle furnaces the ore worked is generally picked to a much greater extent, and therefore the trouble from caking does not amount to as much as it does on the other types of machine furnaces, where equal care is not exercised in picking the ores. Western ores have not yet been roasted in muffle furnaces. There is no reason why they should not be if they are passed through magnetic separators and be later treated to reduce the lead.

Muffle furnaces are those in which the roasting and combustion, or heating chambers, are kept separate, and are only used where the sulphurous gases and the combustion gases must be kept separate from each other. In the ordinary furnaces these gases mix and are allowed to escape to the atmosphere. Wher-

ever the gases are kept separate from each other, it is done for the purpose of regaining the sulphurous fumes for the manufacture of sulphuric acid as a by-product.

Muffle kilns are expensive to build, consume a great amount of fuel, have complicated mechanisms for operating the rabbles, and are very troublesome to operate, requiring constant attention and repairs. The heating and roasting chambers are generally arranged one over the other and may consist of any number of stories. The amount of air admitted into these furnaces must be carefully regulated in order that only sufficient be admitted to supply oxygen to properly unite with the sulphur to form the (S 02) and with the zinc to form the (Zn 0). Any excessive air is bad as it necessitates greater chamber space for condensing the fumes in the acid department. At the present zinc-acid works where the regulation of the air supply to the furnaces is good, a chamber volume of 15 cubic feet per pound of sulphur burned per twenty-four hours is used. The acid made is either 50 degree chamber or 60 degrees tower acid.

The air admitted to the muffle kilns, before entering the roasting hearths, is passed through a series of flues below the lowest combustion chambers. The supply of hot air to the roasting chambers is a very important matter as cold air has a tendency to check the roasting and also is very expensive as to fuel. The hot air is led through flues and is distributed to the different roasting hearths in the proper proportions. The hot gases are drawn from the furnaces by means of rotary fans, built in the brick flues leading to the acid department. Located between the fan and the Glover Tower is a dust chamber where flue dust, etc., are deposited. This results in a clearer acid being produced than is produced at the pyrite acid works.

The manufacture of sulphuric acid from the waste fumes from the roasting furnaces is really a secondary process. The acid being considered a by-product. There is produced to-day nearly four hundred tons of spelter daily, from the ores of which are produced daily under two hundred tons of 60 degree sulphuric acid, while those ores contain enough sulphur to make eight hundred tons of the same acid. From this it will be seen that there is going to waste daily in this industry, enough sulphur to make

over six hundred tons of 60° degree acid, or in tons of sulphur, one hundred and eighty. The reason for this is that the smelters are located in a territory where the market for acid is limited and the selling price low.

From every ton of 60% ore it can be roughly stated that one ton 60 degree acid can be made. In actual practice it is more than one ton acid per ton ore. This large amount of sulphur in the ore has been allowed to go to waste in the great majority of the zinc works. Among those smelters who have investigated the acid end of the works it is recognized that owing to the large amount of sulphur contained in the ore, and also that the roasting process prepartory to smelting the ores is the first step in the manufacture of sulphuric acid, there are to be derived greater profits from the manufacture of acid than from the production of spelter with plants located in a good spelter and acid market. For this, among other reasons, Pittsburg, which is the center of the spelter market and is also a very good acid market, is bound to become the main center of the zinc smelting industry within not many years.

Carbonate and silicate ores are calcined instead of roasted. This is practically the same operation as roasting and consists of driving the carbon-dioxide from the carbonate ores and the water from the silicate ores. There is no real chemical action in calcining, as there is in roasting, where both the zinc and sulphur took up oxygen. In calcining there is no further combining of any of the elements in the ore, the only action is the driving out of the carbon-dioxide and the water by heating, oxygen not being necessary for either expulsion. The carbonates were changed from (Zn C 03) to (Zn 0), the (C 02) passing off. The silicates have the same chemical combination as before calcining (Zn_2 Si 04) unless they were combined as a hydrate, in which case the water is driven out of the combination as is also the moisture in the ore.

It is not necessary to calcine these ores before reducing, however it is more economical to do so, because whether the CO_2 is driven off in the roasting furnace, or whether it is driven off in the reducing furnace, the fuel necessary to bring the ore up to the temperature where the CO_2 is driven off is burned in either

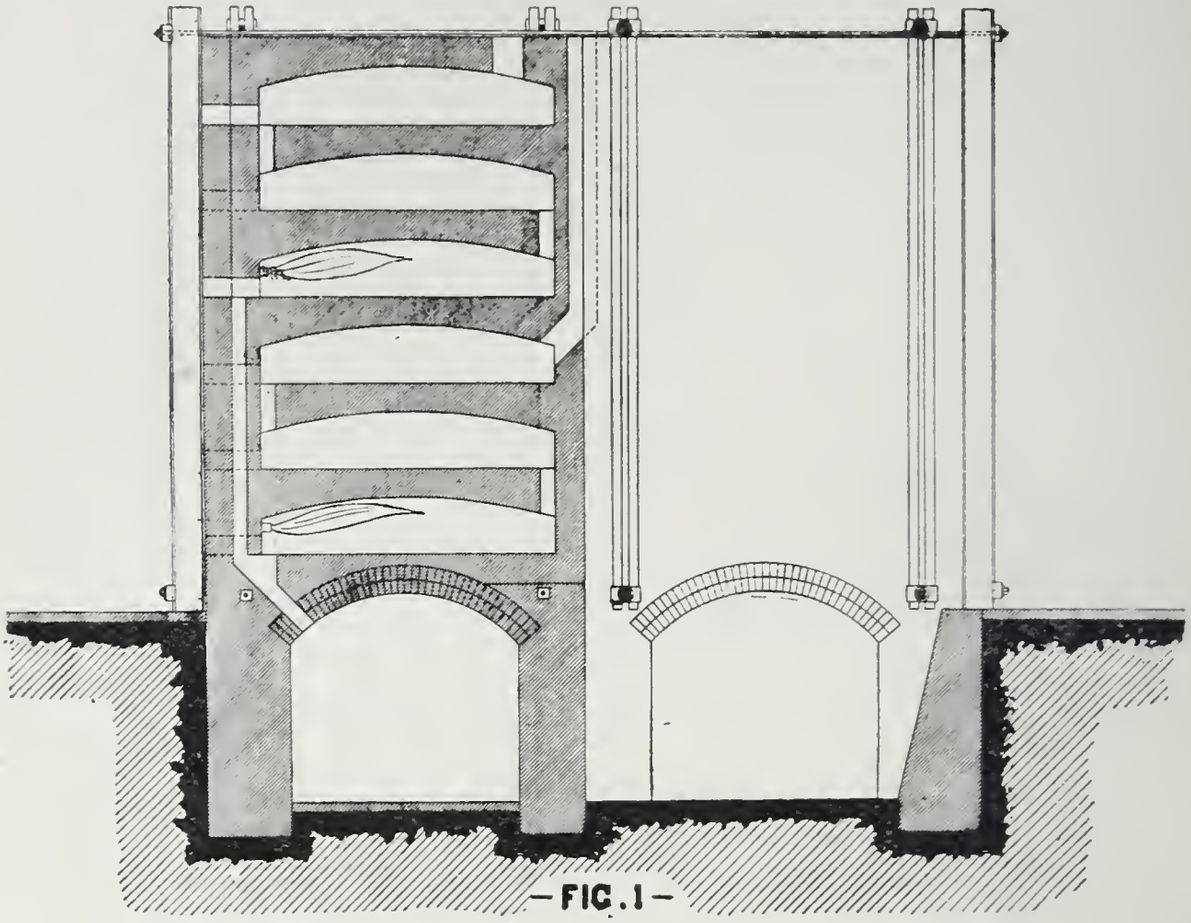
case. In the reducing furnace, as shall be explained later, it would not be as economicaal to drive off this CO_2 as there it must be driven off as CO, which means that just as much extra fuel will be required as it takes to furnish the extra carbon to make all the gasses CO.

In the case of silicate ores, it is economical to calcine because of the harmful effect of the water in the reducing furnaces. However, in actual practice silicate ores are worked in the reducing furnaces without calcining. In fact, the amount of silicate ores worked at the principal smelters is very small.

Neither the carbonate nor the silicate ores run as high in zinc as the sulphide ores do, while from their nature, as well as from the lack of skill in working them, the losses of metal from these ores are greater than those from the sulphide ores. This, when combined with the fact that the quantity of metal in the furnace charge is less than with sulphide ores, while the labor is the same and the fuel consumed to work the poorer charge is somewhat more than with sulphide ores, will explain why the smelters do not smelt carbonate or silicate ores unless absolutely necessary. Silicate ores are preferred to carbonate ores because they can be worked without calcining and also with smaller losses than in working carbonates. A stock of silicate ores is generally kept on hand for emergency sake. Should any damage occur to a roasting furnace, which requires considerable time to repair, and the stock of roasted ore gives out, then the reducing end of the plant can be kept going on silicate ores until a new supply of roasted sulphide ores is provided. On starting up a new plant the roasting furnaces generally fall below the output required by the reducing furnaces, and at this time silicate ores come in very handy to fill up the reducing furnaces. Outside of this for such purposes silicate ores are not desired, and are hardly ever used by the leading smelters.

Now that the requirements of roasting have been explained it is well to give a description of the leading furnaces used for this purpose. The principal types are known as hand, machine and muffle furnaces. Hand furnaces are those in which the ore is turned over and pushed ahead by hand power. The machine furnaces are those in which this is done by mechanical power.

The muffle furnaces are those in which the sulphur gases and the fumes or gases of combustion are not allowed to mingle, and in which the combustion of fuel to supply heat for roasting, takes



—FIG. 1—

place in a separate chamber from the roasting chamber, the heat going to the roasting chamber by radiation.

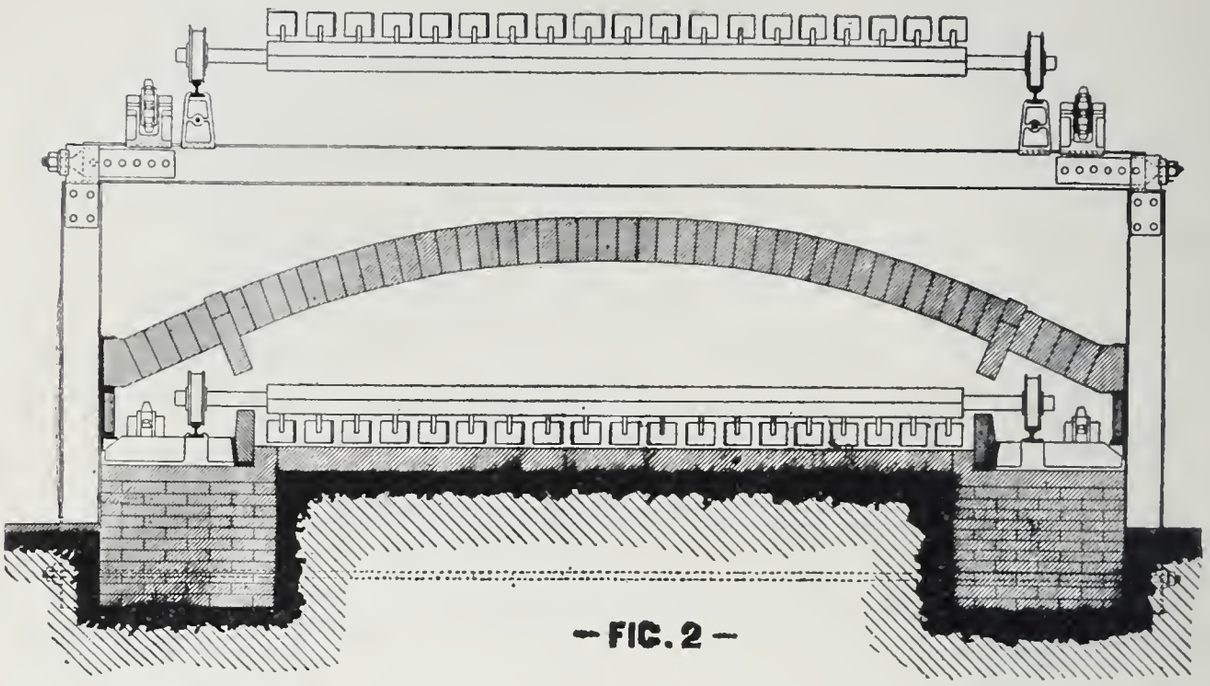
Muffle furnaces can be operated either by hand or machine power. Drawing No. 1 represents in a general way the common type of hand furnace as used by the smelters in the Missouri-Kansas districts. The ore enters through the opening at the top of the furnace, and is spread over the upper hearth, from where, after being well turned over and exposed to the air and to the heat from the gas burners, projecting through the sides, it is pushed forward and drops down through the flue to the next lower hearth. Here it is again worked across the bed and drops down to the next or third hearth. After passing over this hearth it drops through a flue to a cellar or storage bin under the furnace. These furnaces are built too high, and often, too, as many as eight are in a single block. The upper tier of furnaces are

worked from a traveling platform or scaffold. The sulphur fumes pass through the different stories and through a stack to the atmosphere. The gases from these furnaces cannot be used for acid making, as they are too contaminated with the waste gases of combustion.

Beside hand furnaces of this type, there are hand furnaces which are arranged with only one long hearth, the ore entering at one end and is gradually worked across or forward to the other end by hand power. Long, ore-like bars are used in shoving the ore forward, and are applied by extending them through doors or openings along the sides of the hearth, and working the ore forward by swinging these bars across the hearth.

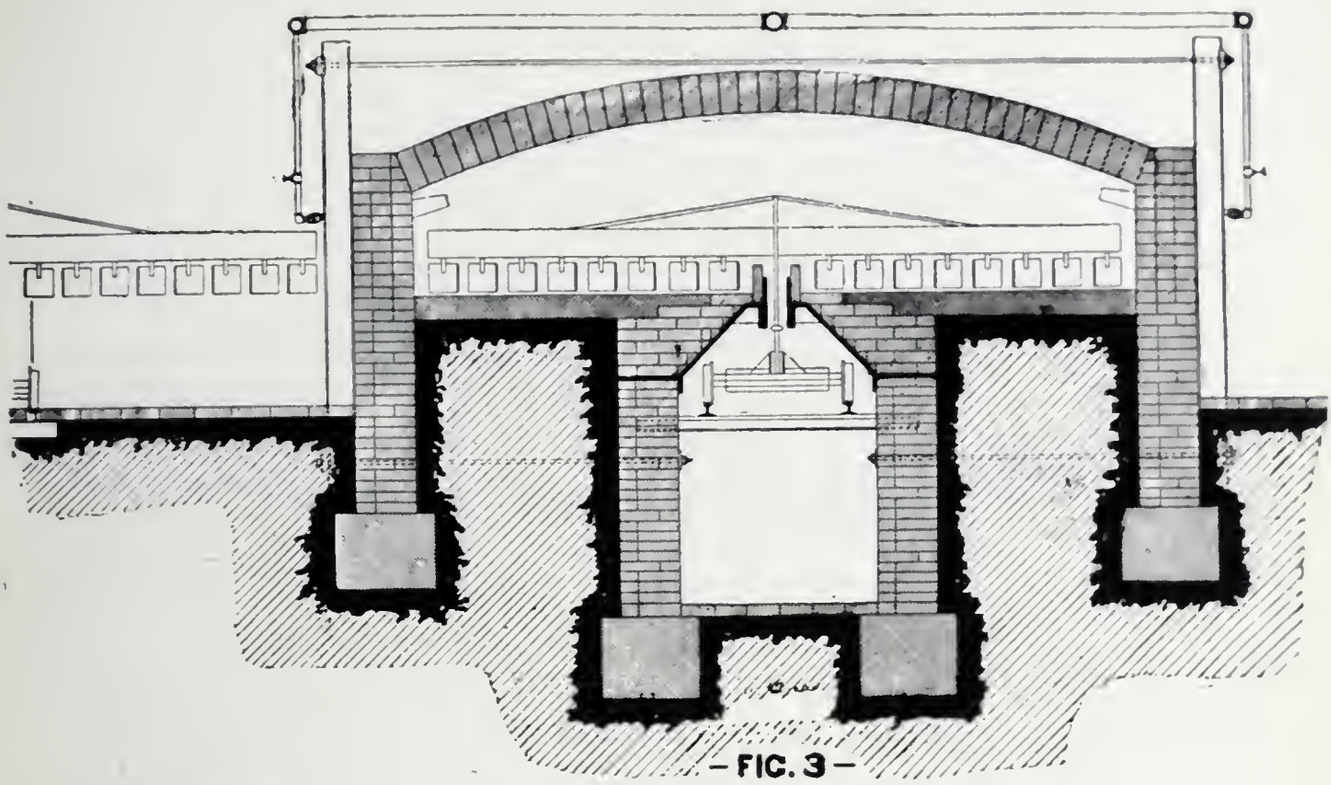
Machine furnaces as far as applied to zinc ore roasting are the development of these long hand furnaces. A rake or rabble, with blades set at an angle, according to the rate of discharge desired, is drawn through the furnace by means of an endless cable. The rabble enters the receiving end and passes through the furnace, plowing up the ore into furrows. The rabbles are attached at suitable distances along the cable, and are similar to each other in all respects except that the blades of each succeeding rabble or rake are so set that they cut into the furrow left by the preceding rabble. In such furnaces the roasting is much more efficient, both as to thoroughness as well as to the quantity roasted per square foot of hearth area. These furnaces are built about 14 feet wide across the hearth, and 150 feet long. It is well known that the oftener the ore is turned over and the air has access to each particle of ore, the greater will be the output and economy of the furnace. It would be desirable that the rabbles pass through as often as possible, however this cannot be done as the temperature of the furnace is so great that after one and one-half circuit of the cable, the rabbles must stop outside of the furnace and cool before they can enter again. If this cooling off is not allowed it does not take more than eight or ten trips of each rabble, through the furnace, before they sag and catch onto the floor or bed of the furnace. Now while the rabbles are cooling outside of the furnace it would not do to keep the cable in the heat unprotected in some manner. To successfully take care of

the cable was the great point to solve in inventing the machine furnace. The two most successful furnaces are the Brown and the Ropp furnaces, shown in cross-section by Drawings Nos. 2



— FIG. 2 —

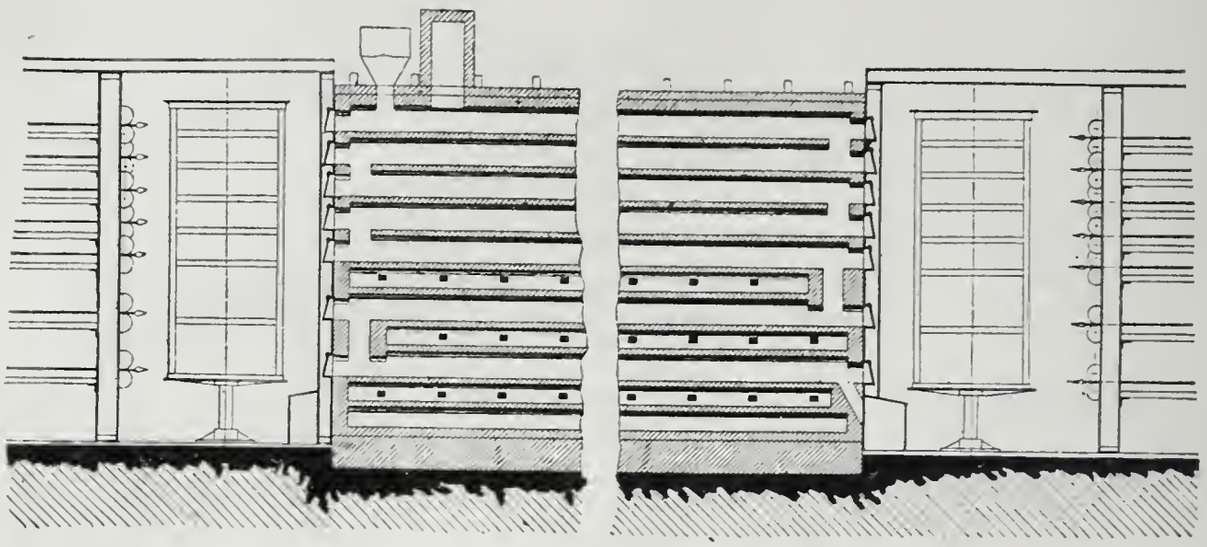
and 3. These two furnaces have unfortunately been the cause of very much patent litigation which prevented their use to a much greater extent than that to which they have been applied. Drawing No. 2 shows the cross-section of the Brown furnace, the rails, cables and trucks of the rabble are in secondary or side chambers to the roasting chamber proper, to which they are connected by means of a long slot running the entire length of the furnace. The rails and cables are kept cool by admitting the supply of air, necessary for the roasting process, through the two side chambers across the rails and cables and then through the slots and into the furnace proper. These furnaces were very successful, and were the best type until Ropp invented his, shown by Drawing No. 3. Here the rabble is carried on a truck which passes through a tunnel under the center of the furnace. The rabble is supported from the truck by means of a plate extending through the slot in the floor. This furnace is recognized as the most economical of the machine furnaces. However, after a long litigation, it has been declared an infringement on the Brown patents. The sulphurous gases from these furnaces also mix with the waste gases of combustion and pass off to the atmos-



— FIG. 3 —

phere. Neither of these furnaces are well adapted to suit the requirements of a muffle furnace, as in them the air supply is not regulated to the extent required for muffle furnaces. The air entering through the slots must be cold to keep the rails and cables cool, while in a muffle furnace hot air is almost essential to procure good results or fuel economy.

Drawing No. 4 represents the cross-section of a muffle furnace, which can be either a hand or a machine furnace. If a hand furnace, the same method for pushing the ore forward is used as was described before. If a machine furnace, then a special mechanical arrangement is required. The furnaces shown have seven roasting hearths and three combustion chambers. The first, third and fifth are combustion chambers, while the second, fourth, sixth, and above that, are roasting chambers. The ore enters the upper hearth from a bin or hopper which dumps a charge into the furnace just as the rabble enters. The rabble is drawn forward by a steel bar which enters from the far end, passes through the furnace, and to where the rabble is attached by means of a hook. This bar recedes, drawing the rabble after it. In this way the ore is worked across the upper hearth and drops to the next lower hearth, from where it is passed forward



-FIG. 4-

by another rabble attached to a similar bar, which drops it to the next hearth and so on, until it passes out of the lowest hearth as roasted ore. The gas for combustion enters the combustion chambers through the pipes indicated, each of which are provided with the necessary gas mixer. The heat passes through the floor to the roasting chamber where as high as 1800 degrees temperature is required. The third and fourth floors are the hottest. The upper floors need not be so hot as the lower floors, as the ore on the upper hearths is richer in sulphur and the heat passing up from the lower hearths is sufficient, together with the heated air for the roasting process, to carry on the roasting. Should the temperature in these upper hearths be too high it will tend to cake the ore.

The air, before being admitted to the different floors, is passed through the flues under the combustion chamber and heated. The doors to the roasting hearths are made of cast iron and are well fitted to close tight to exclude air. The rabbles pass through the furnace only once per hour to keep down the amount of air admitted through the doors. The air is blown through the flues by means of a positive blower, or may be drawn through the flues by means of a positive exhaust fan, which exhausts the sulphurous oxide to the acid department of the works. The gases pass from the hearths and out through the flue over the top of the furnace to the exhaust fan. The gases of combustion are allowed to escape through stacks to the atmosphere.

THE MIXING OF THE CHARGE.

As the ores were graded before being roasted and were passed through the roasting process without mixing the grades, it necessarily follows that the different grades must be stored in different bins until needed for further working.

Since for the reduction of the zinc oxide, which is now the combination in which the zinc is held in the ore, it is necessary to bring that oxide in close contact with carbon that the oxygen may combine with the carbon and thereby liberate the zinc. This is the main reason for mixing. Coal, coal and coke or coke alone are used to supply the carbon of the mixture. They are crushed and screened through a half-inch mesh screen. Another reason for mixing is to average up the zinc contents of the various ores to a uniform standard, as well as to bring the iron contents to as nearly as possible the same daily percentage. Some works consider the amount of lime contained in the ore and also try to control that too. However, the basis on which the combination of grades is figured, is to secure every day a charge containing the same weight of ore and fuel, the same weight of zinc contained, with as nearly as possible the same daily percentage of iron. It is a hard matter to get the same mixture every day, but the aim is to hold it as near as possible to a uniform mixture. On giving the men a bonus for good recovery of metal, and giving them as nearly as possible a uniform charge to work, they become especially skilled in handling that charge, and this has resulted in great economy at some works. As to iron the desire is to keep it down as far as possible, for while it does take up sulphur from what zinc sulphide there remains in the ore and thereby liberates the zinc that it may be regained. it is evident that where the ore was not roasted to under 1% sulphur by weight, that in a charge carrying from one to two per cent. iron there will be considerable iron sulphide formed to attack the clay retorts, eating holes through them and thus causing losses of metal.

After the proper quantities of fuel and different grades of ore have been measured out, water is squirted over the whole mass and it is thoroughly mixed by turning over and over, either by hand or by machine. While water has a very detrimental effect

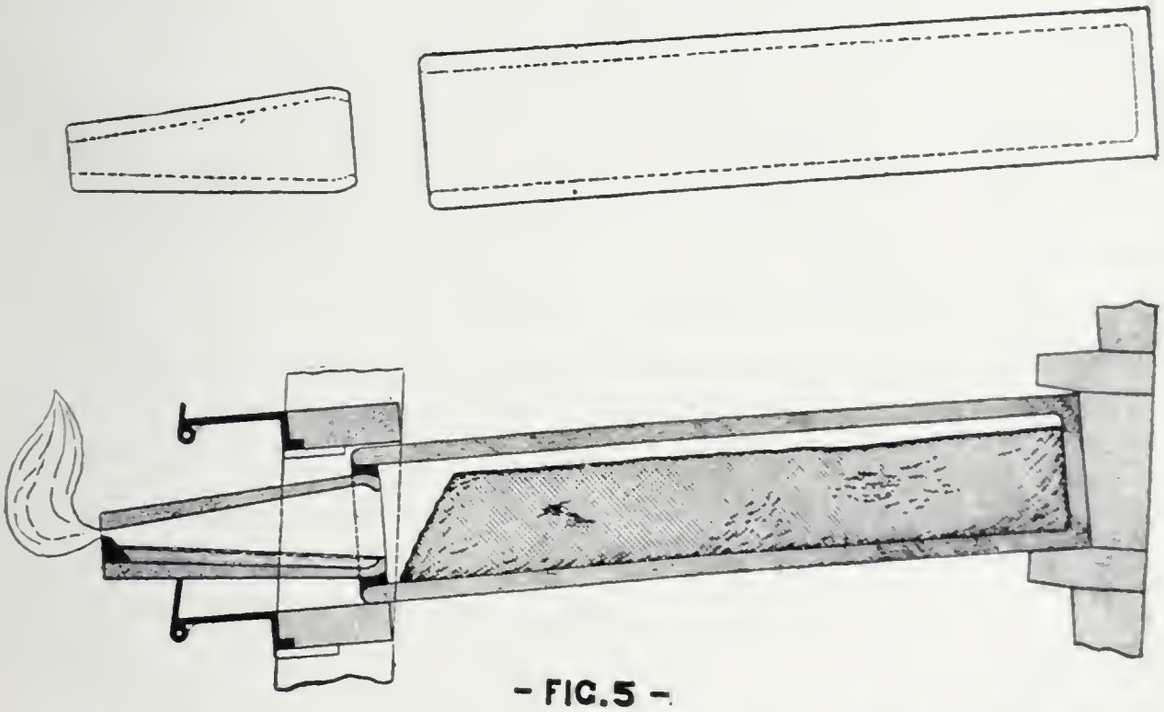
in the retort, it is applied in the charge as this is the only way in which the ore and the fuel can be held together after being mixed. If water was not applied, the ore being much finer than the fuel, and also much heavier, would gradually work to the bottom of the car containing the charge, due to the jarring it receives during transportation to the reducing furnaces, and also in charging it into the retorts. It is of the greatest importance that nothing of this kind occurs, as the degree of success of the reduction process depends more on the thorough mixture of the ore and fuel than on anything else excepting the proper regulation of the temperatures. After mixing, the charge is stored in cars until the time for charging the furnace comes about. In winter these cars should be kept indoors or else considerable trouble is caused by the charge freezing hard.

The effect of poor mixing will be referred to later on.

THE REDUCTION OF THE ORE.

After the charge has been prepared, and the reducing furnaces were cleaned from the residuum of the preceding day's charge, the ore is brought before the furnace in metal cars and is shoveled from the cars into the retorts, care being exercised not to pack it in, so as to interfere with the passage of the vapors and gases. A vent or channel is made at the top of the retort by inserting an iron bar along the top of the charged retort and then withdrawing it. The charge car travels along the face of the furnace as the charging progresses until it has passed along the entire length of the furnace. Following behind the car come the men who place the condensers up into the retorts, and lute the joint with fire clay. The mouth of each condenser is plugged with loam, which is a mixture of coal dust and earth. After the whole of the furnace has been charged, generally about eleven o'clock in the morning, the temperature is brought up to the proper degree and the reducing process begins. Drawing No. 5 shows a view of a retort and a condenser separated and also a sectional view of the two places together, showing the charge in the retort, the plugging in the end of the condenser and the accumulation of metallic zinc in the condenser. Drawing No. 6

shows a cross-section of a modern reducing furnace, which in practice is known as a block, and consists of two complete furnaces, placed back to back. There are four rows of retorts in height and forty in length, making 160 retorts per furnace, or 320 per block. This represents the most economical type of natural gas fired furnaces. Formerly they were made five rows high and sixty-four long, making 320 retorts per furnace, or 640 per block, but were found to be both too high and too long for the proper regulation of heat with natural gas firing. However, for producer gas firing, furnaces are made much larger than either of these; in fact, there are producer gas furnaces in existence having almost 1,000 retorts per block. They are six rows high, and were not found economical, and were partly closed up until only 420 retorts remained for each furnace, or 840 per block. This seems to be the most economical furnace for producer gas firing.



- FIG. 5 -

Referring again to Drawing No. 5, we can follow through the reducing process with this illustration. The ore and coal were charged into the retort at the time when the temperature of the furnace was at its lowest, and when the inside of the open and empty retort recorded a temperature of 1400 degrees. After the charging and placing of the condenser the temperature is gradually raised, evaporating the moisture and the water in the

charge, which is driven out of the mouth of the condenser by the gases arising from the coal. Not long after the operation has commenced, the coal gases come out of the mouth of the condenser hot enough to burn on coming in contact with the oxygen of the air. The temperature of the charge raises very rapidly until it is to the necessary degree for reducing the zinc at about 2300 degrees. The carbon in the retort must come in contact with the zinc oxide to take up the atom of oxygen and thereby liberate the zinc which passes forward as a vapor, together with the carbon monoxide. The carbon monoxide passes out of the mouth of the condenser and there burns, uniting with the second atom of oxygen. The zinc vapors should not pass out of the mouth of the condenser. However, some of the vapors do and unite again with oxygen on coming into the air. The combustion of the zinc gives a greenish white flame at the mouth of the condenser, and it is upon the starting of this flame that the furnace men know that the reduction has begun. The condensers project out of the furnace and have not the high temperature of the retorts. The zinc vapor from the retort on coming into the condensers, condenses into fine drops of metallic zinc which collect on the bottom of the condenser. The regulation of the temperature both in the retort and in the condenser is of great importance, as should the temperature of the condenser be too low the zinc will condense in crystals like snow. There are always inert gases and some carbon dioxide in the retorts and condensers, and the finely divided particles of the condensing vapors, on coming into a lower temperature, have just so much greater affinity for the extra atom of the carbon dioxide which results that these crystals or flakes are small bodies of metallic zinc enclosed in a covering or coating of oxide. To recover this metal it is first necessary to get rid of the oxygen in the coating before the metallic zinc can be melted or vaporized. This is done by recharging these flakes or crystals with carbon and repeating the reducing process. These flakes are known in practice by the term "blue-powder," as is almost every other thing which can be recharged into the retorts.

The reduction of the zinc oxide is not accomplished by bringing carbon monoxide in contact with the roasted ore in the

retort, unless the temperature therein is very high. Then the carbon monoxide will take up the atom of oxygen from the zinc, and unless this atom of oxygen is passed on to other carbon, forming two particles of carbon monoxide, the carbon dioxide will give back to the zinc vapors the extra atom of oxygen when this vapor has been pushed forward into the condenser and becomes cooler, when it again has a great affinity for oxygen. It is this which tends to produce so much blue powder in the condensers. It is evident that any steps taken to keep the temperature of the condensers at that point where the zinc will condense without too much of a drop will result in greater economy. Today at some of the works a high wind getting through the windows, doors or other openings into the buildings will result in the production of a larger amount of blue powder and less spelter. Going back to the carbon, it is shown in practice that the ore must come in contact with the carbon to be reduced. This can only be accomplished by a thorough mixture of the ore and carbon in the mixing department. There is trouble caused in the retorts by what is known as the formation of "green balls," which consist of quantities of ore about as large as a man's fist, sometimes larger and sometimes smaller, with which there has been no carbon mixed. This having been charged into the furnace is found on extracting the residuum from the retorts, and comes out in the form of a caked mass. On analyzing this it is found to have the same zinc contents as the original ore. Since it was in the furnace for the greater part of twenty-four hours, constantly surrounded and very likely penetrated to some extent, by carbon monoxide gases which are constantly formed in the retort, it may be considered as very strong evidence that carbon monoxide does not bring about the reduction in the retort.

The reduction begins about eleven o'clock every morning. The temperature is gradually increased as the amount of zinc in the ore becomes less. About 3 P. M. there is enough metal in the condensers to collect it. At this time about one-half of the zinc contained in the ore has come over into the condensers, and is collected by a man called a drawer. He taps the condensers by scraping the plugging material from the mouth and then by means of special tapping bars, reaches into the condenser

and scrapes out the molten metal and also the accumulated blue powder. He gathers the metal in a ladle, which holds about three hundred po unds, and which either travels on a trolley or on a car. The blue powder is skimmed off the ladle and is shoveled aside in a heap to be remixed and recharged the next day, when about one-fourth of each furnace is charged with such powders, sweepings, etc. The spelter which is gathered at this time is known as first draw spelter, and is the purest grade. However, it is higher in cadmium than the second or third draw spelters. It is considered the best as it is lowest both in lead and iron. Cadmium vaporizes at a lower temperature than zinc, and accordingly goes over into the condenser in the earlier stage of the operation when the condensers are rather low in temperature and the inert gases most abundant. It is at this time that most blue powder is formed, and as would be expected the spelter which is highest in cadmium is the spelter recovered by reducing the blue powder. However, as between the different draws of metal, the first is highest in cadmium, the second less and the third lowest. The second is purer than the third as regards both lead and iron, although it is considerable higher in these metals than the first draw. The third draw is highest in lead and iron. This is due to the fact that it is necessary to increase the temperature of the retort as the zinc contents of the ore decreases, and as the temperature increases there is more lead vaporized and carried over to the condenser and condensed with the zinc. The same regarding the iron.

The second draw is made about 10 p. m. and the third from 3 to 4 o'clock the next morning. After this time the condensers are all taken down and cleaned, the residuum is blown or scraped out of the retorts and the new change inserted. At this time all bad or broken retorts are withdrawn and new ones inserted into the furnace.

The metal recovered from the ore in the different draws are used for different purposes. The first draw metal is sold to a great extent for brass making while such of it as remains after satisfying the demand for this purpose, goes with the second and third draws for galvanizing. For rolling into sheets or bars the first and second draws are melted in a furnace, which while

called a refining furnace only acts as a metal mixer producing a more uniform average grade of metal for the rolls.

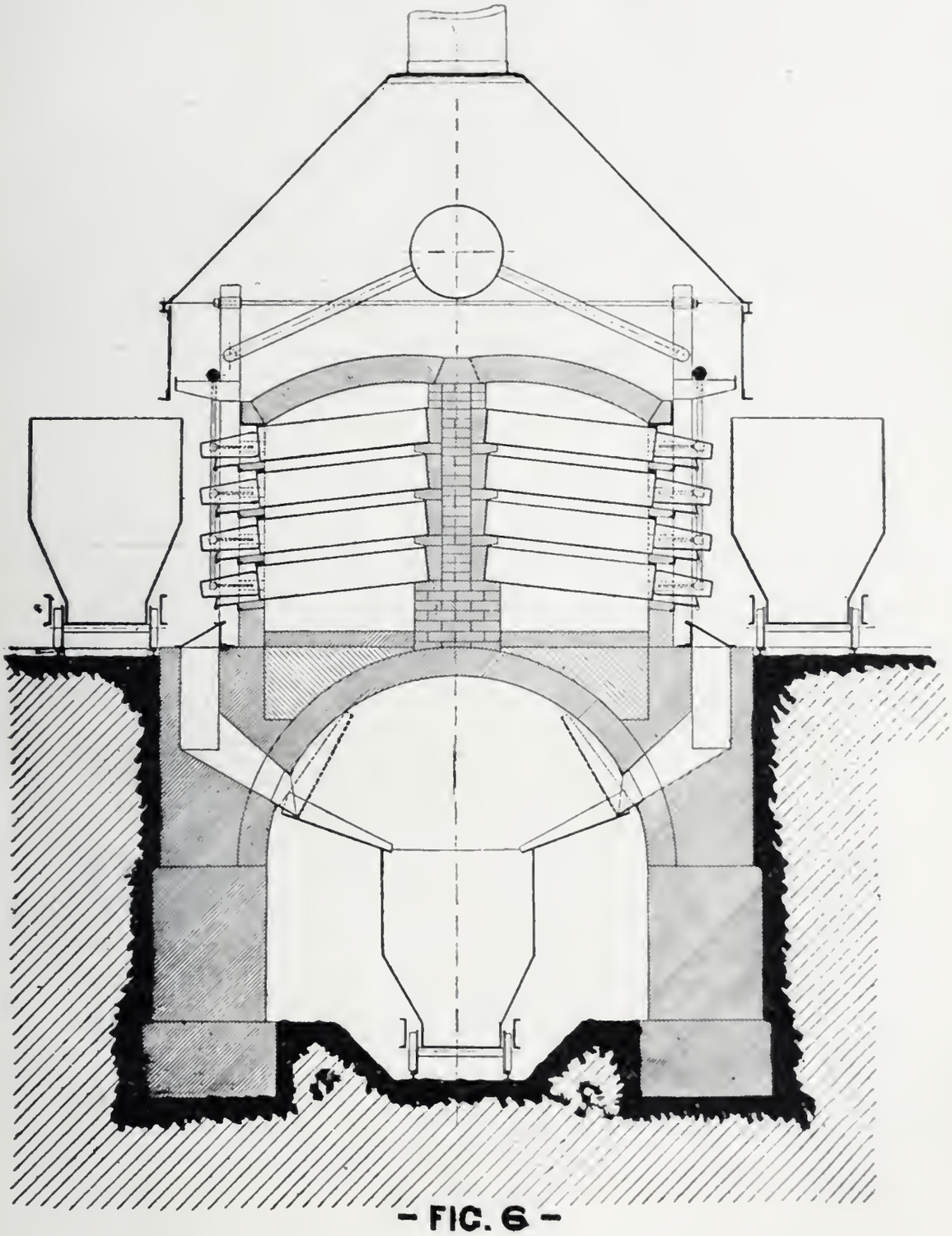
About 50 per cent. of the metal is drawn at the first draw, 33 per cent. at the second and the remaining 17 per cent. at the third draw. A recovery of 87 per cent. of the zinc contained in the ore is considered very good practice. At times this recovery is exceeded and at others it is not reached. The principal losses are due to vapors passing out of the condenser mouths and passing away as zinc oxide, the metal absorbed by the retorts and allowed to pass through them to the furnace, the metal escaping due to holes eaten through the retorts by the iron in the ore, metal held in the slag which accumulates in the retort during the time of reducing and also the metal remaining in the residuum of the charge after the completion of the process.

The residuum contains about 10 per cent. of its weight in zinc and constitutes the most important item of loss. The zinc escaping from the mouths of the condensers requires special sheet metal prolongs to be placed over the ends of the condensers to catch the scaping zinc. However, as every condenser and every prolong must be taken down each day, the extra cost of labor, as well as the original cost of the prolongs, does not justify this method of catching this zinc. The second loss in importance is the loss of metal that takes place the first few days that new retorts are charged. The fire clay retorts when destroyed by excessive heat or by the iron in the ore, are removed from the furnaces and new ones put in their places. The first day no charge is placed in the retort due to the chances of the retort cracking before it is thoroughly burned in the furnace. They are charged the second day and during the following week absorb and pass off to the furnace about thirty-six pounds of zinc. After this time the amount of zinc escaping through the retort is a very small and constant amount. The metal which is absorbed does not remain in the clay walls of the retort but passes through and burns up in the furnace and can be noticed at the smoke stack. There are about eight retorts lost daily per furnace of 320 retorts, and when it is considered that some of the works have as many as thirty furnaces, the loss from this cause is enormous, amounting to between three and four hundred dollars

per day. The only way to reduce this loss is to make a denser retort, and to handle them with greater care. Considerable zinc is taken up by the condensers but that is mostly molten spelter which enters the porous clay. Spelter so absorbed is not necessarily a loss since when these condensers give out the inside half inch of the clay walls is chipped out, and crushed up and mixed with the blue powder and is charged into the furnace to be reworked. About fifty condensers are required daily for a 640 retort block. They are made of a poorer grade of clay than that of which the retorts are made, as they are not subjected to the same heat as the retorts are. Wherever the iron eats holes through the retorts the gases and the zinc vapors can escape into the furnace, and out of the stack provided the air and gas pressure in the furnace is not too great, in which case the gases and zinc vapors are blown out of the mouths of the condensers with more force than is exerted at the rest of the retorts. In this manner the furnace men can detect the damaged retorts during the smelting process.

After the third draw is made the furnaces are cleaned. This is done by taking down all of the condensers, setting them on their ends and shaking out the oxide, etc., hanging in them. At some of the works long iron bars are use to scrape out the residuum (ashes) and the slag from the retorts, while others apply a simpler method which at the same time is a very hard one on the retorts. They have a traveling shield suspended from a trolley track before the furnace. Through this shield there is a vertical row of holes corresponding to the row of retorts. A pipe nozzle attached to a hose is inserted through the hole and into the retort. A jet of water is injected into the retort while it is very hot, this water turns into steam and blows out the residuum against the shield from where it falls through chutes to the cellar or tunnel under the furnace. This method is very hard on the retorts and does not blow out all of the slag which remains behind to take up much valuable room and to interfere with the heating.

To produce zinc from the spelter the most economical way is to re-distill the spelter in special refining furnaces. These refining furnaces are in all respects similar to the reducing furnaces with



- FIG. 6 -

the exception that the retorts are inclined downward in the furnace, which is the opposite to the inclination of the retorts in the reducing furnace. The condensers should have a dam on the butt end to prevent the zinc from running back into the retort. Spelter is charged into the retorts in the form of bars which are passed though the condensers to the retort. The zinc vaporizes and passes over to the condenser at a much lower temperature than is required in the reducing furnace. The impurities or contaminating metals remain behind in the retort, and are discharged after a considerable amount has accumulated.

The principal product of the smelters is spelter and not zinc. The amount of zinc used in this country would only require about six weeks' time for either one of the two largest smelters to produce that amount.

In presenting this paper, the object in view was not only to describe the process of smelting zinc ores, but also to call attention to an industry, which when combined with the manufacture of sulphuric acid as a by-product, is one especially adapted to the natural and trade advantages which we possess in Pittsburgh.

We not only have an abundance of fuel and good shipping facilities, but in our manufacturing plants an enormous amount of spelter and acid is used daily, especially in such branches of the steel industry where the product is galvanized.

There is every reason to believe that the zinc industry, in connection with the manufacture of sulphuric acid, shall become one in which Pittsburg ranks as leader; the same position as we now occupy in the steel and glass industries. We have such advantages that such a work once established in this district, and properly managed, need fear no competition from plants located outside of the Pittsburgh district.

DISCUSSION.

MR. CAMP—If there are any points not made clear to the members in this very thorough paper, Mr. Diescher would be glad to bring them out.

MR. HIRSCH—I would like to ask Mr. Diescher the size of the retorts in Figure 5.

MR. DIESCHER—The retorts are 11½" diameter outside, 8½" inside, and from 48" to 52" long, according to the practice at the different works. Each retort gives daily about 25 pounds of spelter per day. I think the largest works in the country has 10,000 retorts; another has over 9,000. In all there are about 40,000 retorts in the country.

MR. SHIRAS—I would like to ask what proportion of fuel and ore is used in the retort.

MR. DIESCHER—In roasting the green ore, the fuel required, where they use producer gas, is about equal in weight to the ore. For the entire process, using producer gas both in the roasting furnaces and also in the reducing furnaces from five to six tons of fuel are required per ton of spleter produced. It takes about two tons of ore to give one ton of spelter. As to the coal in the charge, some works mix about an equal weight of coal to the weight of ore; however, an excessive amount of coal in the charge is not necessarily a waste, because they crush the coal so as to pass through a ½" screen and screen the residuum through a ¼" screen. All over ¼" is coke and is used over. If they would crush it finer it would be a waste. The only oxygen in the retort is the oxygen combined with the zinc. Only so much fuel is consumed as is required to unite with that oxygen.

MR. WILKINS—Do they use anthracite or soft coal?

MR. DIESCHER—In some of the works they use anthracite dust; in other works they use what is known as a "dead" coal. The Illinois plants, as a rule, buy up the anthracite dust from the coal yards of Chicago and Cleveland and use that. It is a better grade of coal; there is less sulphur in it, which is an important thing; less ashes than there are in this "dead" coal; and it results in somewhat less slag in the retorts.

MR. ANDERSON—Is the coal from the Pittsburgh District satisfactory?

MR. DIESCHER—Yes, coal from the Pittsburgh district would be good for smelting. The coal they use is the very top layer from the surface mines of Kansas and contains very much foreign matter. They do not pay the attention to getting a good grade of coal that they ought to. For some reason some of the smelters

are very backward about interfering with the coal; they claim the men are accustomed to working with that coal and if they gave them a different quality it might be a disturbing element as to economical working. The works you mention are located near the lake district and they prefer to use the anthracite dust rather than the soft coal. They both have also their own soft coal mines. There is another point about the Illinois and the M. & H. plants that Mr. Wilkins' remark reminds me of. That is their location away from the ore supply. It takes about two tons of ore to give one ton of spelter. The best practice is to recover—well, anyways from 1040 to 1100 pounds of spelter to a ton of ore. Now the freight rate on ore is almost the same as the freight rate on spelter. The Kansas smelters are all located within 100 miles of Joplin. They were formerly located nearer to Joplin, but have gone farther away on account of the discovery of the gas fields, but still in shipping the ore instead of the spelter, using producer gas for firing, the Illinois plants earn larger profits than the other plants do.

MR. WILKINS—Do you think, if you have to bring two tons of ore to Pittsburgh as against one ton of spelter, would that be a financial success?

MR. DIESCHER—Sixty per cent. ore contains from 500 to 600 lbs. sulphur and from this sulphuric acid is made as a by-product. Out West they have no market for the acid. In Pittsburgh they have a very good market for it at from $13 to $14 per ton 60° acid against $7 to $8 in the West. For this reason it is more economical to ship the ore here and recover the spelter and acid from it.

MR. WILKINS—Well, I know that the Illinois Company went into the fertilizer business in order to get rid of their by-product of sulphuric acid.

MR. DIESCHER—Yes. The farmers claim the soil out in Kansas has not been worked long enough and they do not need a fertilizer, so the acid cannot be applied to that purpose for some time to come.

MR. WILKINS—Well, I know the sale of the fertilizer goes very largely towards the profits of those works out there.

MR. DIESCHER—Well, that is at the Illinois works. The

greatest points for the consumption of fertilizer are in Illinois and Indiana. In Pittsburgh there are used over 200 tons of spelter per day, and from 250 to 300 tons of acid. The principal consumers of acid in Pittsburgh, are the galvanizers, and they also use the spelter.

MR. ANDERSON—Do they use the sulphuric acid for fertilizer throughout this part of the country?

MR. DIESCHER—Yes, but it could be used here to better advantage for other purposes.

MR. BABBIT—Are the fumes from the muffle furnace high enough in sulphur to be used for the catalytic process?

MR. DIESCHER—Yes. In Germany several works use the catalytic process altogether, and one plant in Wisconsin is using it; they are using platinum as the contact material.

MR. WILKINS—I move a vote of thanks to Mr. Diescher for his paper. He has treated a very scientific subject in a very plain manner, which everybody could understand. I think it is an admirable paper.

Motion seconded and carried unanimously.

MR. MAURY—In regard to the cost of roasting by the two processes for roasting the ore, what is the difference between them?

MR. DIESCHER—The difference in the costs of roasting, as far as fuel goes is somewhat in favor of the second process. The principal difference is the difference resulting from the interest on a larger investment and also in the labor charges for operating furnaces of the different types. Now take a muffle furnace; the output of the furnace shown is about 42 tons of roasted ore, corresponding to 50 tons of green ore, per day. It takes 6 men to handle it per 12-hour shift, or 12 men per every 24 hours. In the West they are paid about $1.90, so it would be less than $.50 per ton for labor. In either of the other two types of machine furnaces one man will handle two furnaces for one turn of 12 hours, which would be one man per furnace for 24 hours, at $2.00 per day. They roast about 40,000 pounds of green ore, or 20 tons, per day. That would be 20 tons handled by one man for $2.00, which

would be 10c per ton, against 50c per ton in the former case. This is for the actual roasting and does not include handling ore to or from the furnace.

MR. WILKINS—I am a little disappointed that you did not give a plan of some of the works that you have in your mind, showing how the labor charges have been reduced. I notice at some of the Illinois plants the labor charge is simply immense. Another thing I have noticed out there; they do not seem to have discovered that there are drop-bottom cars. They get their ore in box cars and have to shovel it out by hand, and instead of shoveling it into the bins at once they take it around to the tracks that they have especially for it. I think they do not intend to reduce the labor charges.

MR. DIESCHER—No, there has been nothing done in that way, for this reason. The mining of ore is carried on by a large number of miners. They can not get a full carload of one grade of ore. A miner will sell his ore as soon as he has a cart load or so of it, and the ore from every mine is different. In fact the ore from day to day in one mine will be different; so it is impossible to get a carload of ore that you could take in a hopper car and not divide it off. And then there are few hopper cars in the west. There is this one point that must be considered; the tonage handled at one of those works is so small—take the M. & H. works, I do not think they handle more than about 120 tons of green ore per day and it is handled so often and over such an immense space in the plant that the cost of installing conveying machinery or systems is so great that the interest on the investment is more than can be saved by the installation. If the plant was to be rebuilt and arranged so that a narrow gauge system could be used it would be all right, but the present plants are so arranged that it is a hard thing to install an efficient narrow gauge system. If you were designing a new plant it would be all right to use a narrow gauge system.

A question was here asked as to the continuance of the ore supply and what guarantee there was as to the supply.

MR. DIESCHER—The only guarantee you have as to output of the mines is simply to look back over the output for years and

years and that the output has been increasing right along. There is one point that I wish to speak of further and that is in reference to the western ores. They are by-products from gold and silver mines that have accumulated for years. The miners could not sell these ores as the smelters would not buy them, although they contain as high as 20 ounces of silver and some gold. The zinc content is so high as to cause great losses in the working of the ores, for gold and silver. As the smelters would not buy them, the miners stacked them up outside the mines. Ores containing above 40 per cent. zinc can be treated but anything under 40 per cent. is not found by the smelters to be worth working. There are great quantities of the low grade ore throughout the west and of late years there have been investigations made to find out some way of recovering the zinc ore from these ores of less than, say 30 to 35 per cent. zinc, separating or eliminating the iron and lead. If that can be done there is an enormous field in the West for ore.

MR. BABBIT—Would there be much demand for bag-house product, or is it too fine?

MR. DIESCHER—No; if you could get it free from lead it would be all right, but is too fine to smelt. It could be smelted if you would break in a crew of men into working it, but I remember of one case where they sent back to the smelter, over 500 pounds of dross from a refining furnace. It was charged into the reducing furnace and they got out but 25 pounds of metal as the men were not skilled in working it.

MR. BABBIT—Where we had 20 per cent. zinc and 9 per cent. copper in the ore, half of that zinc goes off as fumes. Now would that be bad, even for ordinary reduction purposes if caught in a bag room?

MR. DIESCHER—No, if you could get a constant supply of it they would soon learn how to work it. (Showed sample of zinc oxide made from the ashes of the reducing furnace.)

MR. FLANAGAN—What is the difference between the Ropp furnace and the Edgar furnace?

MR. DIESCHER—The Edgar Zinc Works have the Brown furnace.

MR. FLANAGAN—What is the difference between it and the Zellweger furnace?

Question answered by Mr. Diescher illustrating on blackboard.

MR. YARDSLEY—What would be the investment required for a plant such as you would propose to put in the Pittsburgh district?

MR. DIESCHER—The investment for works, making 32 tons of spelter and 60 tons of sulphuric acid daily, would be from $400,000 to $425,000 in Pittsburgh, without working capital.

MR. YARDSLEY—There are some plants out there that manufacture the sulphuric acid as a by-product of zinc ores.

MR. DIESCHER—Yes, they get about $7.00 to $8.00 per ton for their acid.

MR. YARDSLEY—What is the working capital?

MR. DIESCHER—About $150,000.

MR. YARDSLEY—How many men would it require to operate it?

MR. DIESCHER—In this plant there would be required 200 men.

MR. YARDSLEY—What is the price of zinc?

MR. DIESCHER—Last year the average price was 5.4c per pound.

MR. CAMP—Before a motion to adjourn is in order, I wish to announce that at the Board meeting last Saturday Mr. Worthington was elected a member of the Board to fill the unexpired term of the late Mr. S. M. Taylor.

Motion to adjourn seconded and carried.

CHARLES W. RIDINGER,
Secretary.

CHEMICAL SECTION.

PITTSBURGH, PA., February 18, 1904.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held this evening with the Pittsburgh Section of the American Chemical Society at the rooms of the Engineers' Society at 410 Penn Avenue.

Mr. H. E. Walthers, Chairman, presided. The minutes of the December and January meetings were read and approved.

The paper of the evening, "The Analysis of Grease," by Mr. P. H. Conradson, was read and was very concise and very much enjoyed and appreciated and will prove of much value to chemists having this class of work to handle.

Discussion followed, a number of the members taking part in the discussion.

A vote of thanks was tendered Mr. Conradson for his very able paper.

No further business before the Society, on motion duly seconded adjourned to meet March 17th, 1904.

GEORGE P. MAURY,
Secretary.

ANALYSES OF LUBRICATING GREASES.

BY P. H. CONRADSON.

FRANKLIN, PA.

Members of the Pittsburgh Section, American Chemical Society—*Gentlemen*—Your President has requested me to give a talk or paper on the analyses of solid lubricants, or as they generally are called, lubricating greases, before this Section of the Society. The President in his letters of request says, that he desires some papers by practical chemists, and that the literature on the subject "Grease" is not plentiful.

A satisfactory examination or analyses of lubricating greases is, to say the least, tedious and complicated, even in a laboratory suitably equipped for this class of work, and I can readily appreciate the feeling of you practical chemists, whose main chemical work around this section of the country, is anything but greasy, when your manager sends you a tub of "grease," asking you to analyze the same, and tell him what it is made of, and if it is good for anything, and what, and perhaps how it is made.

Before entering upon the chemical analysis and discussion of suitable methods, it might be well as a practical introduction, to say a few words about greases in general, so as to acquaint you with the multitudinous materials or substances that enter, and are more or less used in compounding the numerous kinds and classes of lubricating greases found in the market.

The market price for these greases vary, all the way from $1\frac{1}{2}$ cents up to 15 cents per pound, and naturally the grease manufacturer uses, and has to use, very cheap and inferior materials to enable him to manufacture and sell at a profit, greases at such low figures, as the prices of the cheapest greases indicate: hence, the materials used for such cheap compounds are to a large extent, waste materials or residues from petroleum distillation, mixed with waste, fatty substances, and cheap inert mineral matter of all kinds and description; on the other hand, the more expensive

greases are generally compounded from good, pure materials suitable for the purpose.

However, it should be borne in mind, that a cheap grease, that is the price of the grease, may not be any indication whatsoever, as to the suitability of the grease for certain work, any more than the most expensive grease would be any better suitable for certain kinds of work.

Now, in making an examination of a lubricating grease, a chemical analysis alone does not tell all the story to enable the chemist to form a proper conclusion as to the lubricating value of the grease as such, or in comparison with other greases, and that is just exactly what the practical manager wants us to tell him; therefore to make him an intelligent and practical report, a further study of the grease in question is necessary. Some knowledge of the compounding or manufacture of greases greatly facilitates one in judging the quality of the same.

I will therefore briefly touch upon a few points that may be of interest or of value to you.

The lubricating grease question, when it comes to the comparative lubricating value of the various compounds in the market, it is a rather difficult one to answer intelligently, unless one knows the special work or kind of machinery the grease or greases in question are intended. Like everything else, one kind or grade of grease can not be made that would be equally good or suitable for all kinds of work or machinery, hence to make fair comparisons between two greases, the essential point to bear in mind is primarily, "what kind or class of machinery to be lubricated, is the grease intended?"

Without going into any lengthy details as to the various kinds or classes of machinery for which the various greases now in the market are used, it will suffice to mention as extremes, the slow running, heavy, hot rolling machinery in iron and steel mills, to the comparatively light and fast running electric motors. Naturally a grease suitable for hot neck journals in a rolling mill, would not do at all for electric motors, and vice versa.

Therefore as said above, to give an intelligent opinion as to the lubricating value of any grease in comparison with another grease or set of greases, the kind and class of machinery and

work, must be known and taken into account as a basis for comparison, together with the chemical composition and physical properties or behavior of the grease or greases.

The various greases in the market may be divided as regards chemical, physical and mechanical composition into four main groups or classes, and each one of these in as many more subclasses or divisions:

First. Greases made with alkali soaps, as hardener.

Second. Greases made with fatty oil lime soaps.

Third. Greases made with rosin oil lime soaps.

Fourth. Greases made both with alkali and lime soaps.

Besides these there are greases containing magnesia, zinc, alumina, and lead soaps. The greases in each of these main groups vary greatly in composition, both in kind, quality and percentage of the various ingredients entering into the compounds. They may contain from "none" up to 50 to 60 per cent. of bad, good or indifferent mineral matter, such as clay, chalk, soap-stone, graphite, lime, talcum, etc., from practically no *water,* up to 20 or 30 per cent.; from 4 or 5 per cent. up to 50 or 60 per cent. of soap; from no free fatty oils up to 40 or 50 per cent. petroleum oils of better or poorer quality, petroleum residues, rosin, oils, coal tar oils, etc.

The grease in consistency may be soft, medium, hard with softening and melting points varying from 90—100° F. up to 400° —450° F.

From the above you will readily appreciate the variety of greases or solid lubricants now for sale in the market, some good, some indifferent, and some unsuitable for the purpose for which they were intended.

As an intermediate class of lubricants, between the real solid greases, and fluid lubricants (oils), we may consider the so-called solidified oils; they have a soft jelly-like consistency, which should not vary much, if any, within reasonable temperature ranges, that is, they should retain their normal solid consistency within practical working temperature limits.

Having in the above briefly called your attention to the rather complex compounds that you may be called upon to examine, I will now proceed to describe the method or methods I use in my

work, and find them to be more or less satisfactory from a practical and technical point of view. I say practical and technical, because to make a complete and accurate chemical analysis of some of the lubricating greases sold, would, indeed, be a very thankless and tedious task, unless you were requested to make a grease exactly similar in composition and behavior.

I generally submit lubricating greases to the following tests and analyses, which enables me to form a pretty good idea about the quality and composition of the same.

1. Consistency of the grease. Soft, medium or hard.

2. Color. Dark or light, etc

3. Odor. Tarry or asphaltic or resinous, etc. Oftentimes the odor of the grease gives quite an indication as to the nature of at least some of the materials that may be present, principally tarry matter, and rosin oils.

Behavior of grease when submitted to heat:

4. Softening Point. The temperature at which the grease begins to become soft, when carefully warmed or heated.

5. Insipient melting point. The temperature at which the grease begins to partially melt, oftentimes with separation of the oily or fatty matter from the soap and mineral matter.

6. Melting Point. The temperature at which the grease is completely melted.

7. Flashing Point. The temperature at which inflammable vapors are given off, indicated by applying a small flame.

8. Burning Point. The temperature at which the grease begins to burn, when flame is applied.

9. Note if the grease foams or swells and spatters during heating, this indicates the presence of more or less water.

Some greases when heated to make the above tests, foam or swell much until the water is driven off, others remain quiet and melt uniformly; others again partly melt at a comparatively low temperature, with the separation of the soaps in solid lumps, or the settling out of the mineral matter to the bottom of the vessel.

It is well to carefully note the behavior of the greases in these respects, as the practical value of a lubricating grease to a large extent depends upon how it acts when heated, or in coming

in contact with hot journals and bearings, or how high a temperature it will stand before it begins to decompose or separate out.

A grease that stands a good or high temperature, before melting or separation of the ingredients or compounds, is naturally much better adapted for some work, than a grease that separates readily when warmed or heated, other things being equal.

CHEMICAL TESTS.

1. Put 10 grams grease in a 300 c. c. wide neck Erlmeyer flask, add 50 to 75 c. c. 88° B gasoline, break up or disintegrate the grease with a glass rod, then add 200 c. c. more gasoline, shaking well at intervals several times, let stand and settle, pour off or syphon off the clear, suprenatent liquid, without disturbing the precipitate and, if necessary, filter; to the remaining contents in the glass add 100 to 125 c. c. 88° gasoline, shake, let stand and settle, pour off the clear liquid, transfer the insoluble in the flask, to a sufficient large filter, let drain, rinse out flask with 88° gasoline, and wash contents on filter a couple of times, or until the gasoline goes through practically colorless; let drain.

2. Evaporate the mixed gasoline extracts, best in an ordinary tinned iron drinking cup to small bulk, transfer to small weighed beaker, evaporate on steam or water bath, until practically constant weight. The residue in the weighed beaker will contain all the oils in the grease.

The insoluble contents on the filter from the above gasoline treatment, after draining off the gasoline (keep funnel covered) but before beginning to dry, is transferred to a weighed dish, in case the same (residue) has a light color, i. e., appears to be free from tarry or asphaltic matter, insoluble in the gasoline, and dried to practical constant weight, as described later in 4, if not, transfer same back to the Erlmeyer flask, and add a mixture of 20 c. c. strong ethyl ether and 10 c. c. chloroform, digest at ordinary temperature with frequent shaking, transfer contents in flask to same filter, let drain and rinse out flask with some of the ether chloroform mixture; let drain.

3. Evaporate the ether-chloroform extract in weighed dish on steam or water bath. This will contain the tarry and asphaltic matter insoluble in gasoline and possible traces of soaps.

4. Transfer the insoluble from the ether chloroform treatment to a weighed dish, dry first at low temperature on top of air bath, then in the air bath with gradual rise of temperature from 200 to 250° F. until practical constant weight. The dried residue contains all the mineral matter, if any is present, and the insoluble soaps.

5. The weight of this (4) with the weight of the asphaltic matter, if present and the oils found in No. 2 added together and subtracted from 100 gives the amount of water present by difference (also, of course, any small amount of oil volatilizing at 212° F. a temperature necessary to use to drive off the last of the gasoline from the oils.

6. *Mineral Matter.* In stirring up the grease in No. 2 with the gasoline and giving the contents in the flask a rotary motion, it is very easy to see if any free mineral matter is present, as the soaps generally are quite flocculent and stay suspended in the gasoline some little time, while the heavy dense mineral matter noticed is very small, merely traced, it comes from the slacked lime or soda used in compounding the grease, and can be neglected.

7. If mineral matter is present in larger amount put 5 *grams* grease into flask, add 100 c. c. of a mixture of 30 c. c. pure spirits turpentine, 30 c. c. 72° B. benzine and 70 c. c. strong alcohol (this mixture becomes perfectly clear and uniform when warmed a little), put flask on steam or water bath, connect with return condenser, boil gently, shaking occasionally until grease is dissolved, except the mineral matter (this mixture will dissolve by gentle boiling all the soaps, fats and oils), lower the heat so as to stop boiling, let stand a few minutes, then filter rapidly while hot into another flask, transfer insoluble to filter, wash once or twice with above mixture hot.

8. The insoluble on the filter contains all the free mineral matter. Finish off the washing with some benzine, and lastly with some alcohol, dry and weigh, and, if so desired, determine the mineral matter, kind, quality and amount. Add the benzine alcohol washings to 9 after the soaps are decomposed.

9. The filtrate in the flask contains all the soaps and oils in the grease, put the flask on steam or water bath, connect up

with return condenser, heat until liquid becomes clear, then add 2 or 3 grams oxalic acid, either in dry form or dissolved in a little alcohol, boil and shake well for some time; the oxalic acid will decompose the soaps, forming insoluble oxalates with oxides, which thus can be readily separated and determined by well known methods.

10. In case the grease is free from mineral matter, then of course this procedure can be omitted, and the dry soaps (4) from the first gasoline treatment carefully ignited, and the base determined.

4. The flashing and burning points of greases will indicate whether a high fire test oil is used. The consistency of the separated oils will indicate whether a thin fluid, thick petroleum oil is used. In some of the more expensive greases, such as light colored cup, greases good grades of neutral filtered petroleum oils, or heavy paraffine oils are generally used. In cheap mill greases, dark colored or black petroleum oils or residues are generally used.

The above described method is simple enough, and for all practical purposes answers quite well. However, for a more accurate and complete analysis some additional work is necessary.

First. In the gasoline treatment, a little of the lime and magnesia soaps will generally dissolve (the soda soaps are practically insoluble) and if zinc, alumnia, and lead soaps should be present, a considerable amount of these would dissolve; however, as a rule these three latter soaps would hardly occur, except in special greases; therefore the separated and weighed oils will contain a little lime and magnesia soaps.

Second. The separated oils from the gasoline treatment, after weighed should be saponified, to determine the amount of free fatty oils, if any; whether rosin oil is present or not, tar oils, and the quantity of the petroleum oils used.

Third. In some alkali soap greases, free caustic and carbonate of soda may occur, even though free saponifiable fats are found.

12. To free the separated oils from the small amount of dissolved soaps in the gasoline treatment, this can be done either before or after the separated oils are weighed.

In the former case, evaporate the gasoline mixture (2) down to 50 or 75 c. c., transfer to conical glass stoppered separatory funnel, add 0.5 to 1 gram dried oxalic acid, dissolved in 10 c. c. strong alcohol, shake repeatedly for some time, let stand and settle, if any soaps should be present, a precipitate of oxalates will form, add 20 c. c. water to the funnel, shake well, let stand and settle, draw off watery fluid, and wash contents in funnel two or three times with water, add the washings to the first watery liquid and evaporate to dryness and determine the amount and kind of oxides in the oxalates, and then calculate the amount found in corresponding soaps, using oleic acid as standard factor and add amount to the weight of insoluble soaps from the first gasoline treatment.

13. Transfer the remaining gasoline liquid in the separatory funnel to a small weighed beaker, exaporate on steam or water bath until constant weight, this gives the percentage of oils, plus the free fatty acids, from the decomposed soaps.

If present in larger amounts than negligible, they should be determined.

I find the following simple method quite satisfactory in most cases. Extract 5 or 10 grams of the grease with 88° gasoline as described under No. 1; dry the insoluble residue containing the free alkalies, if any, in the same flask in which the extraction was made, to free from water. Add 50 to 100 c. c. strong neutral alcohol and warm, until the alkali soaps are dissolved, filter, and wash with strong warm neutral alcohol. Add phenol-phtalein to the united alcoholic solutions, and if alkaline, titre with quarter ($\frac{1}{4}$) normal HCL, calculate the amount of free caustic alkali from the number of c. c. HCL used. Treat the insoluble from the alcoholic treatment with water, filter. Add methyl orange to the filtrate; if alkaline titre with quarter ($\frac{1}{4}$) normal HCL, and calculate the amount of alkali carbonate from the number of c. c. HCL used. If the grease also should contain lime soaps it is well to ascertain if free caustic lime is present.

14. Transfer the weighed oils after noting the consistency and color, etc., by means of 88° gasoline to a 300 c. c. saponifying flask and add 50 c. c. neutral strong alcohol and a few drops phenolphtaline, neutralizing with standard potash solution, noting

the number of c. c. used from which the amount of free fatty acids, due to the decomposed soaps, can be calculated, and subtracted from the weight of the oil in the beaker.

15. Saponify the oils in the flask (14) with standard alcohol potash, according to any of the well known methods, such as described in Allen's and Lewkowitsch's Chemical Analyses of Fats, Oils,. and Petroleums. After separating and determining the amount of saponifiable fats present, the quality and kind of the saponifiable oils, can be examined according to methods also described in the above works.

16. To determine free caustic and carbonate of soda in greases, methods described under soap analyses by Allen & Lewkowitsch can be followed.

QUALITATIVE TESTS FOR ROSIN OIL.

I have found the following simple method quite satisfactory to ascertain whether or not rosin is present in greases.

To 10 grams grease in a wide neck flask, add 25 c. c. strong alcohol, break up the grease completely with a glass rod, and digest for awhile at a gentle heat, (80° to 90° F.) with frequent shaking, let settle, pour off the liquid onto a dry filter, and add 25 c. c. more strong alcohol to the flask, and repeat the treatment.

To the united filtered alcoholic extracts, add a little phenolphtaline as indicator, and add one-quarter normal KOH in slight excess. Evaporate down to dispel all the alcohol and stir up the residue with 24 to 30 c. c. 88° gasoline, let settle, pour off the clear liquid to free the same from gasoline. The residue will contain most of the rosin oil, if present, with a little mineral oils, and can readily be used for necessary identification tests for rosin oils as described by Allen and Lewkowitsch, and others, such as,

1. Renard's Test. Rosin oil 10 to 12 drops treat with anhydrous stannic chloride or stannic bromide (one drop) develops a beautiful violet coloration.

2. Linderman's Test. Some of the above residue shaken with a little acetic anhydride at a gentle heat; after cooling the acetic anhydride, draw off by means of a pipette, and test by adding one drop of strong sulphuric acid, if rosin oil is present, a fine violet coloration is produced. Besides these tests, the gravity,

taste, and odor, especially on warming the residue readily gives evidence of presence of rosin oil. Of course, it is always well at the same time to make a comparative blank test, using mineral oil somewhat similar in nature to the mineral oil found in the grease.

I generally submit lubricating greases to the following tests and analysis, which enables me to form a pretty good idea about the quality and composition of the same.

PHYSICAL TESTS OF GREASES.

1. Consistency of the grease. Soft, medium or hard.

2. Color. Dark or light, etc.

3. Odor. Tarry asphalic or resinous, etc. Oftentimes the odor of the grease gives quite an indication as to the nature of at least some of the materials that may be present, principally tarry matter and rosin oils.

4. Softening point. The temperature at which the grease begins to become soft, when carefully warmed and heated.

5. Incipient melting point. The temperature at which the grease begins to partially melt, oftentimes with separation of the oily or fatty matter from the soap and mineral matter.

6. Melting point. The temperature at which the grease is completely melted.

7. Flashing point. The temperature at which inflammable vapors are given off, indicated by applying a small flame.

8. Burning point. The temperature at which the grease begins to burn, when flame is applied.

9. Note. If the grease foams or swells and spatters during heating, this indicates the presence of more or less water.

Some grease when heated to make the above tests, foam and swell much, until the water is driven off, others remain quiet and melt uniformly, others again partly melt at a comparative low temperature, with the separation of the soaps in solid lumps, or the settling out of the mineral matter to the bottom of the vessel.

ANALYSIS OF SAMPLES OF GREASES.

	No. 1.	No. 2.	No. 3.
Color	Dirty Yellow	Dark	Dirty Yellow
Odor	Rosin	.....	Rosin
Consistency	Very Soft	Hard	Medium
Softening point	.....	225° F.	160° F.
Melting point	Flows at 85° F	415° F.	250° F.
Flashing point	385° F.	540° F.	350° F.
Burning point	450° F.	.....	400° F.
Soda Soaps	.....	53.17%	.....
Lime, magnesia soaps	5.68%	.....	13.12%
Mineral or Hydrocarbon oils	91.95%	32.32%	84.90%
Water	2.37%	14.51%	2.00
Grav. of separated oil	23.5° Baume	.....	Trace lime
Free mineral matter	.....	Little Graphite	23.0° Baume

Behavior on heating. Greases foam some on heating. Nos. 2 and 3 have a tendency to separate into oil and lumps of soap.

The mineral oil in No. 2 is a thick, heavy at ordinary temperature, nearly solid, dark colored oil.

Mineral oils in Nos. 1 and 3, yellow colored. These two latter greases are compounded with rosin oils.

P. H. CONRADSON,
Franklin, Pa.

February 1, 1904.

The following method, with acocmpanying photograph showing a saponifying apparatus, I have found very useful and convenient in saponifying compounded lubricating oils, especially those containing thick heavy petroleum oils, such as valve and cylinder oils, and, of course, the apparatus is equally well adapted for any oil or fat.

APPARATUS.

1. A 300 c. c. solid pure silver flask (made for me by Queen & Co., of Philadelphia) with wide and true ground neck, shape of flask as shown in the photograph.

2. A medium Soxhlet's extraction tube filled with glass beads or broken marbles up to or a little above the upper bend of the syphon tube.

3. A 12" glass return condenser, according to Allihn.

4. 1, 2 and 3 properly connected with good corks, and placed on a tripod, on which rests two asbestos blocks, as shown

in the photograph, a thinner under one, and a thicker one with tapered holes cut out in the center to fit the silver flask; between the two asbestos blocks or plates is put an iron ring on which rests a smaller iron plate, fitting the somewhat concave shape of the bottom of the silver flask. All these parts are clearly indicated as shown on the photograph.

With an apparatus fitted up in this way, there is no danger of flask breaking; it can be left to itself, and a direct gas flame used for the boiling.

Having a great deal of this kind of work to perform, I soon found glass flasks very unsatisfactory either from breaking, or the caustic potash solution used in saponifying soon begins to act on the glass in the flasks to such an extent as to seriously interfere with obtaining correct results. I, therefore, conceived the idea of having a couple of silver flasks made as shown in the photograph, and they have given entire satisfaction.

They have been in constant use for the last four or five years and now are as good as ever.

The Soxhlet's tube acts like an automatic agitator by the intermittent filling and emptying through the syphon tube, thus facilitating the saponifying process.

STANDARD ALCOHOLIC POTASH SOLUTION USED IN SAPONIFYING FATS AND OILS.

I used practically a one-half normal alcoholic caustic potash solution made as follows: 50 grams pure caustic potash, dissolved in 680 c. c. pure 95 per cent. grain alcohol, let the solution stand for a while in a dark place to settle, then filter through asbestos filter, and add to the filtrate 300 c. c. distilled water, shaking well, and let the solution stand for a day before standardizing. 25 c. c. of this solution requires about 50 c. c. of one-fourth normal HCL (hydrochloric acid). To standardize this alcoholic potash solution, I proceed exactly in the same way as in saponifying oils, which will be described below, besides standardizing the same direct with one-quarter normal hyrochloric acid, and one-quarter normal caustic potash using phenolphtaline as indicator.

SAPONIFICATION PROCESS OF COMPOUNDING OILS.

The amount of oil taken depends upon the amount of saponifiable fat or oil that is expected to be present in the sample, varying from 2½ up to 10 grams. If the oil contains 35% to 65% saponifiable fat or oil, I use 5 grams, and if less than 20%, 10 grams.

Weigh out the oil in a small beaker, warm if necessary, transfer the oil from the beaker to the silver flask by means of 15 to 20 c. c. 88° gasoline, add 25 c. c. of the standard alcohol caustic potash solution from a 25 c. c. pipette (after drawing up the solution in the pipette to a little above the mark, wipe off the outside lower part of the pipette) let the pipette drain, have 80 c. c. strong neutral alcohol in a 100 c. c. measure, draw up alcohol into the pipette about 20 to 25 c. c. at a time, so as to rinse out the pipette and let alcohol run into flask. In this way the pipette is entirely freed from the potash solution, adhering to the inside walls and sides of the pipette. Connect up the flask as shown in the photograph, and already described, boil quite briskly from 5 to 8 hours.

Heavy thick compounded oils, such as cylinder and valve oils, containing heavy petroleum stocks, take longer time to saponify than thin light oils. After boiling a sufficient length of time, shut off the heat, remove the silver flask, and any alcohol that may be in the Soxhlet's tube add to the flask. Then proceed to titre to determine the amount of caustic potash used in saponifying the oil. To this end add a little phenolphtaline as indicator to the flask, and add gradually HCL (one-quarter normal and standardized against one-quarter normal KOH) in small excess, or until the red color disappears on shaking (owing to the wide mouth and neck it is very easy to see when the red color has gone, even with dark colored oils); then transfer the contents in the silver flask to a 300 c. c. glass flask, rinse out the former with a little neutral alcohol and a little 74° benzine, add to the silver flask 5 c. c. hot water, and 2 c. c. of the quarter normal HCL, and shake (this to dissolve any potash that might remain in the silver flask) and add this to the contents in the glass flask, put on steam or water bath and heat to boiling, boil for a few minutes, (this to drive off any carbolic acid that might be present), then neutralize the con-

tents in the flask with one-quarter normal KOH and calculate in the usual way how much caustic potash has been used from the number of c. c. required and from it the amount of saponifiable fat present.

For most fats and oils such as tallow, oil, lard oil, cotton-seed oil, maize or corn oil, the same standard factor or equivalent can be used. If rape, colza or sperm oils are present, of course, it will be necessary to separate the total free fatty acids, and from this calculate the amount of saponifiable fats present.

P. H. CONRADSON,
Franklin, Pa.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's hall, 410 Penn ave., Pittsburgh, Feb. 24, 1904.

Section called to order by the Chairman, Mr. Frans Engstrom, at 8:30 P. M., sixteen members and visitors being present.

Brief address by the Chairman.

Discussion of the subject for the evening, Highway Bridges, was opened with a paper by Mr. C. M. Canady, and was participated in by Messrs. A. Stucci, Fitzgerald, Duckham, P. Bryun, Chas. Worthington, Chas. Davis and Frans Engstrom.

On motion a vote of thanks was tendered to Mr. Canady for his able paper.

Subject selected for the next meeting, March 23d, "Blast Furnace Slag as a Structural Material," on which a paper will be presented by Mr. George Shinn.

On motion Section adjourned at 9:50 P. M.

CHAS. WORTHINGTON,
Secretary, pro tem.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred forty-third regular monthly meeting of the Engineer's Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, March 15, 1904, at 8:25 o'clock. Vice president, Samuel Diescher, in the chair and 55 members and visitors present.

The minutes of the previous meeting were read and approved.

The Board of Directors report that they have passed favorably on the following applications for membership, and present same to the society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
JOHN T. BEALOR,	John T. Bealor Mfg. Co., Heating and Ventilating. 1118 Westinghouse Bldg., Pittsburg, Pa.	J. F. Kuntz, W. M. Judd, W. O. Abbott.
ALEXANDER BEESON,	Manager, Pittsburg-Buffalo Co.'s Plant at Johnetta. Johnetta, Armstrong Co., Pa.	J. M. Searle, J. P. Young, C. W. Ridinger.
EDWARD PATRICK DONOHUE,	Supt. of Transpt. At Eliza Furnaces of Jones & Laughlins Steel Co. h., Mobile and Monongahela Aves., Hazelwood, Pittsburg, Pa.	E. L. Messler, R. P. Kernohan, M. J. Dowling.
CADWALLADER EVANS, JR.,	Supt., Blaine Coal Co., Elizabeth, Pa.	E. P. Vankirk, Chas. F. Scott, Wm. Bradford.
FRANK M. FABER,	Vice Pres. and Gen'l Mgr. of the Liberty Mfg. Co., Pittsburg, Pa. 6905 Susquehanna St., Pittsburg, Pa.	N. C. Wilson, John W. Landis, W. D. Corcoran.
BURT GELLATLY,	Member of firm Gellatly Co., Times Bldg., Pittsburg, Pa. h., 446 Rebecca St., Pittsburg, Pa.	Chas. W. Ridinger, Warren I. Bickford, Geo. T. Barnsley.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
MORGAN W. HALL,	Mechanical Engineer, Jones & Laughlins Steel Co. h., 5919 Alder St., Pittsburg, Pa.	D. L. Mekeel, J. L. Klindworth, P. H. Hasbrouck.
C. LUDLOW LIVINGSTON,	An Attorney-at-Law and Solicitor in Patent Causes. 1102 Frick Bldg., Pittsburg, Pa. h., Oakmont, Pa.	D. C. Ashworth, Geo. T. Barnsley, Chas. W. Ridinger.
WM. ALEXANDER MOORE,	Chief Engineer, Schuylkill Valley Illuminating Co. and Montgomery & Street Ry. Co., h., Phœnix Hotel, Phœnixville, Pa.	Harry H. Heffrin, Walter Kennedy, Geo. T. Barnsley.
FRANK D. PURDY,	In Turbine Dept., of Westinghouse Machine Co. h., 201 Colonial Bldg., Wilkinsburg, Pa., P. O. Box 121.	W. J. Auburn, J. L. Moore, Richard Hirsch.
DANIEL TURPIT,	District Supt., for the Babcock & Wilcox Co., 1218 Frick Bldg., Pittsburg, Pa.	Geo. P. Maury, Chas. W. Ridinger, Geo. T. Barnsley.
RALPH C. WOOD,	Draftsman, with the Penna. Lines West of Pittsburg. h., 225 44th St., Pittsburg, Pa.	G. C. Schade, James K. Lyons, F. L. White.

Voted that the secretary cast a ballot electing the gentlemen to membership.

The board also reported that at the meeting held Monday evening, March 14, it was unanimously voted to recommend the names of Wm. Metcalf and Thos. H. Johnson to the society for honorary members, the same having been proposed in accordance with Section 3, Article I, of the By-Laws.

Voted that the secretary be instructed to cast a unanimous vote electing those gentlemen to honorary membership.

MR. BANSLEY—As Chairman of the Reception Committee for the present year, it is my duty to make a report of the reception tendered the members of the society at the Farmers' Bank Building last Saturday, and from all reports that come to me from those who were present it was quite a successful affair. The Farmers' Bank Building, being one of Pittsburg's

sky scrapers was thought to be of interest to the members of this society and we secured an invitation to inspect it from basement to roof. After viewing the armor plate vaults in the basement, the party proceeded to the 24th floor and from there to the roof, where we were given the opportunity of seeing Pittsburg by night; from there we went to the apartments of Mr. E. K. Morse, on the 24th floor, where we found a large number of nice red apples awaiting us. Unfortunately Mr. Morse was not able to be there himself, or it is likely he would have opened a barrel of cider as well. From the 24th floor we went to the offices of the Pressed Steel Car Co., where a very nice luncheon was served to the members and we were treated quite royally.

Secretary reads report of the Committee to revise By-Laws of the Society as follows:

Mr. J. M. Camp, President Engineers' Society of Western Pennsylvania.

DEAR SIR—Your committee appointed at last meeting to revise By-Laws of the Society have considered the matter and recommend the following:

That Section 3 of Article I, of By-Laws be changed to read as follows:

Honorary members shall be proposed by at least ten members, and require a unanimous recommendation by the Board of Direction to the Society *at the Annual Meeting.*

Not more than one Honorary Member shall be elected in any one year.

The names of the nominees shall be published the same as those of the applicants for active membership and voted upon in the same manner, but the election must be unanimous. The secretary shall promptly notify the person elected as honorary member, and if an acceptance is not received within three months, the election shall be cancelled.

Respectfully submitted,

S. M. KINTNER,
W. A. BOLE,
RICHARD HIRSCH.

MR. SCOTT—I move that the Secretary be instructed to publish it in the monthly notice to the members as a proposed change of the By-Laws to come before the society at the next meeting. (Motion carried.)

VICE PRESIDENT—We shall now hear the papers of this evening. The first paper is by Mr. C. Renshaw, on "Present Electrical Railway Practice." (Paper will be published later.)

VICE PRESIDENT—The second paper will be read by Mr. P. M. Lincoln, on "Adaptation of Alternating Current to Railway Purposes."

ADAPTATION OF ALTERNATING CURRENTS TO RAILWAYS.

BY MR. P. M. LINCOLN.

To the engineer electricity is a means—not an end. In this respect the engineer differs from the scientist. To the scientist the study of electric manifestations is the end in view and he is satisfied if he discovers some new manifestation, or a new method of measurement, or a property of electricity previously unknown. The view point of the engineer is quite different. He is interested in electricity—not because of what it is, but because of what it will do. The engineer has in mind the accomplishment of some practical end, such as the driving of factories, the operation of elevators, the lighting of buildings and streets, and the transportation of passengers and freight. Electricity is to him merely a means of solving such problems as come before him.

The particular engineering problem which we are to discuss this evening is that of transportation. The engineer has applied electricity to the solution of certain phases of the transportation problem because by its use he secures an agent which does his work both more economically and more efficiently than by other means at his disposal.

As an indication that the railway engineer has been able to adapt electricity to accomplish his ends, or perhaps it would be more correct to say that the electrical engineer has successfully applied electrical methods to the operation of railways, may be cited the fact that the capital at present invested in electric railway enterprises has reached the enormous total of about $2,500,000,000. What is more surprising is the fact that this total development has taken place within a period of time considerably less than twenty years.

The development of electric railroading up to the present time has been somewhat peculiar in one respect, and that is that

the type of motor which has been employed has remained practically unchanged since the earliest development. Sprague, in his work at Richmond in 1887, which may be called the first commercial development of electric railroading, used the direct current series motor and today, with almost no exceptions, all traction enterprises using electricity as a motive power are using this same type of motor. The test of time and the trial of other types of motors has only served to prove still more conclusively the superiority of the series motor for traction purposes.

An analysis, on the one hand, of the requirements of traction in general and, on the other hand, of the properties of the direct current series motor, led to the conclusion that the superiority of this type of motor is due principally to the two following reasons:

1st. Because the motor is inherently a variable speed motor. It will, on account of this property, automatically adjust its speed to the load conditions that it is called upon to meet.

2nd. Because its torque varies nearly in proportion to the square of the electric current input. In other types of motor the torque varies at a slower rate than the square of the current input. This property evidently reduces the amount of current required for a given tractive effort, other things being equal, over that required by another type. These two features are the ones which have made the direct current series motor pre-eminent up to date in the railway field.

The motor, however, is by no means the only element in the traction problem. The entire problem may, for the purpose of our discussion this evening, be divided into three elements:

1st. The generation of power.

2nd. The transmission of power from the generating station to the cars or trains.

3rd. The application of power to the cars or trains.

The requirements of the third element have demanded a motor characteristic as good as that of the present direct current series motor. Since nothing better for traction purposes than the direct current series motor has been offered, the result is that the other elements of the system have been subservient to the motor

requirements. As the electric traction has developed with time, the handicap introduced by the necessity of using the direct current series motor for the operation of trains or cars has been more and more apparent. To gain an adequate idea of the traction problem as it exists today, it may be well to glance hurriedly at the course which has been followed by the development of electric traction.

The original Richmond plant, which was referred to above, consisted: 1st. Of a power station which generated electric current at approximately 500 volts. 2nd. A transmission system of sufficient capacity to take the current from the power station to the cars without an undue amount of loss. 3rd. Direct current series motors upon the cars.

For a number of years this was the universal method of procedure. The time came, however, when the distances and the amounts of power required by the cars or trains were so great as to require a prohibitive amount of copper to carry current from the generating station to the cars with this system. The evident remedies were two. 1st. To put in more power stations; and 2d, to generate a higher voltage at the power house.

The disadvantages of the first horn of this dilemma were generally recognized to be the greater. Therefore the necessity for this higher voltage brought into use the so-called booster system, which may be considered as the second era in the development of the railway traction problem. By means of these boosters, the voltage generated at the power station and transmitted to the more distant parts of the system was made to vary automatically with the current transmitted. The amount of this variation was adjusted to the losses which would occur in the transmission to these more distant parts so that the voltage supplied to the cars would not exceed the normal. The system was one which was uneconomical in its use of power and the continued extent of electric traction both in regard to train weights and distances soon demanded something better.

It was then recognized that the transmission element of the system was the one which was deficient. Again it became a question between the multiplication of the number of power gen-

erating joints or the increase of transmission voltage, and again the electrical engineer cast about him for some way of avoiding the necessity for increasing the number of generating stations.

It began to be recognized that to gain the voltages necessary for transmission, alternating current would have to be used. The demands of the motor equipment, however, still made necessary the retention of the direct current series motor because no alternating current motor had been developed of such characteristics as to justify abandoning the direct current motor. The result of these conditions was naturally the rotary converter substation system which is so general today. This system is, as indicated above, a natural development and is designed to meet the two prime requisites of electric traction as it has existed up to date. These requisites are—

1st. A high tension transmission voltage. By high tension I mean high compared to the voltages usually used in electric traction. The proper voltage for a given case depends upon the condition, and the range to select from is a wide one—from a minimum of perhaps 2,000 volts to a maximum of say 50,000 volts. The transmission voltages that are in common use on traction lines are 10,000, 15,000 and 20,000. Voltages of this magnitude are out of the question with direct current since any high voltage direct current generating arrangement is both very expensive and deficient from an engineering standpoint. Alternating current, therefore, is a necessary accompaniment of high transmission voltage.

2nd. The second requisite is, as indicated above, the use of direct current series motors, since that type is the only one extant, until recently, which possessed suitable characteristics for traction purposes. The requirements of A. C. on the transmission line and D. C. on the motors of course made necessary a connecting link in the rotary converter, which with its compliment of "step-down" transformers is capable of taking energy from the high tension A. C. transmission lines and delivering to the trolley in the shape of direct current at a voltage of from 500 to 700.

The defects of this system are apparent. Further, the most glaring ones are evidently due to the necessity of retaining the

D. C. motor on the train. An analysis shows that the most apparent disadvantages of the rotary converter system are—

1st. The necessity of using the rotary converter. It is an expensive piece of machinery; it absorbs a considerable amount of power (about 10% of the power passing through it under the conditions of usual interurban operation); it is expensive to maintain; it is a difficult piece of apparatus to get started, an operation consuming both time and skill on the part of the operator; the load which it will carry is limited to a maximum set by conditions of commutation as well as to an average set by limits of temperature; it is a piece of moving machinery and consequently requires constant skilled attendance.

2nd, The necessity of distributing power from the rotary substations to the trains at a voltage which is low enough to allow of direct application to the motors. Direct current series motors, although eminently suited to traction work, still have certain disadvantages. One of the worst is its tendency under certain conditions to flash; that is, its tendency to arc over from brush to brush on the commutator. Another disadvantage, but one not peculiar to the D. C. motor, lies in the difficulty of maintaining the motor insulation. Both of these disadvantages are exaggerated by increasing the voltage. Experience has demonstrated the maximum voltage which can be safely taken care of under the severe conditions of street railway practice possibly as high as 700, although 650 is usually the limit, and 550 is in much more common use that either of these higher voltages. When we come to consider distribution problems, this maximum of 650 to 700 volts works a decided hardship. To distribute power from the substations to car requires a certain investment for distributing conductors and entails a certain loss of power. To decrease this first cost of conductors, or to decrease the loss of power, or both, the electrical engineer either must raise the voltage of his distributing circuits or must decrease the distance of distribution. With direct current we have already noted the considerations of the motor limits, the voltage of distribution, and the adoption of the remaining course means the consequent increase in number of rotary converter stations and therefore increased yearly expense for at-

tendance and up-keep. The best the engineer can do, therefore, is to strike a balance between these two opposing forces—initial cost of and losses in the distributing circuits, on the one hand, and initial cost of and skilled attendance on rotary substations, on the other—and find the point where the total cost to his client is a minimum.

It has been long recognized that a motor which could operate on alternating current and which would possess at the same time the favorable speed and torque characteristics of the direct current series motor would avoid the disadvantages which are most pronounced in the present D. C. system.

In fact, the advantage of a higher distributing voltage and the avoidance of rotary converter substations has induced some European engineers to forego the advantages of the speed and torque characteristics of the direct current series motor and adopt the induction A. C. motor for traction on some European lines. The induction motor is inherently a constant speed motor and is therefore in no wise fitted for railway purposes where a large proportion of the work is done at a varying speed. This system has the additional disadvantage of requiring two or more overhead trolleys. This, together with the unfit motor characteristics, were sufficient to condemn it in the eyes of American engineers, and it, consequently, has found no favor on this side of the water. In the opinion of American engineers the advantages obtained were not sufficient to overcome the advantages sacrificed. Deficient though it is, the system showed up well beside the rotary converter system and only served to show still further the need of an alternating current motor with suitable characteristics.

Pittsburgers should feel proud of the fact that the problem of developing an adequate alternating current motor for traction purposes has been attacked and solved by a Pittsburg man, Mr. B. G. Lamme, of the Westinghouse Electric & Mfg. Co. Mr. Lamme has had in mind for many years the advantages which would accrue to an alternating current motor with the speed and torque characteristics of the D. C. series motor. As far back as 1893, Mr. Lamme made experiments on the same type of motor which he has later developed so successfully. At that time, how-

ever, the problem of electric traction was not sufficiently advanced to make the alternating current motor generally acceptable. The D. C. generating stations and motors were entirely sufficient for the needs of that day. As time went on, however, and the need of the alternating current motor became more and more apparent, the problem of building such a motor was again taken up. The basis of Mr. Lamme's work on alternating current motor is the fact than an ordinary D. C. series motor will operate in the same direction, no matter what be the direction of current through it as a whole. Reversal in direction of rotation of the D. C. series motor is obtained by reversing the direction of current travel through the field relative to the armature. From the fact that it makes no difference which way the current travels through the motor, it follows that if the current be reversed very frequently the direction of rotation and the speed torque characteristics will not be interfered with. It follows, therefore, that the commercial direct current series motor is of a type which will operate successfully on alternating current, provided the frequency of alternation be slow enough. The introduction of alternating currents of commercial frequency with this type of motor, however, brings up many problems to be solved before such a motor can be successful. The principal difficulties involved are—

(1) The commutation.

(2) The losses due to circulation of alternating current.

(3) High self-induction.

These various problems have been attacked and solved by Mr. Lamme. Many people have an idea that there is something mysterious about the operation of the single phase railway motor, that its successful operation is due to some occult reason. Nothing is further from the truth. The success of the A. C. single phase motor has been obtained primarily by the adoption of simple and well-known principles and overcoming by sheer excellence of design the difficulties encountered.

The system and motor which Mr. Lamme proposes were described by him in a paper before the American Institute of Electrical Engineers, read in September, 1902, about eighteen months

ago. The reading of this paper was the signal for immediate activity along the same lines by manufacturers of electrical apparatus, both in this country and in Europe. Since the paper was published a number of single phase A. C. motors have been announced. Every one of these motors followed the lines laid down by Mr. Lamme in his paper before the A. I. E. E. One of the first criticisms of the Lamme motor on its announcement was that there was nothing new about it—that he had used no new principle—that others had built similar motors years before. Let all these things be granted, yet the great difference between is that his motor is a success. But this digresses somewhat from the subject.

We pointed out above that the general electric traction problem was made up of three elements—generation, transmission and application. The substitution of the alternating current motor for the direct current will make practically no change in the first and last elements, except the simple changing of the direct current for alternating current motors. The transmission element, for the purpose of this analysis may be divided into two parts—1st, High tension transmission from generators to sub-stations; and 2nd, Distribution from sub-stations to cars. To the first part the substitution of A. C. will make little change—simply that from polyphase transmission to single phase. The second part will be modified by the abolition of the rotary converter and the adoption in general of higher A. C. distributing voltage in place of the 500 to 600 volts D. C. of the present day. All that will remain of the substation will be simply the static transformer. In the alternating current system the substations will, in general, be considerably more frequent.

The current will be taken from the high tension line and by the static transformers reduced to a potential which can safely be put upon the trolley. Just what this trolley potential will be will depend solely upon the element of safety and not, as heretofore. ment of the railway traction problem. By means of these boosters upon the element of commutation and motor insulation. The rotary converter being omitted from the substation will do away with the necessity of skilled attendants. A large element of oper-

ating expenses at every substation will, therefore, be avoided. The avoidance of operating expenses makes possible putting these substations more frequently, consequently the distance which the current will have to go from the substations to the trains or cars will be much shorter. This will in turn affect both the cost of the conducting system to take the current from the substation to the cars and will also reduce the losses.

Although it is simply a repetition in a different form of material that has been published before, I wish to close this paper with a recapitulation of the advantages as well as the disadvantages of using A. C. single phase motors as against the present system wherein rotary converters and D. C. motors are used.

Among the advantages are—

1st. The abolition of the voltage limit for distributing circuits. When it is understood that the cost in the present D. C. system of the distributing circuits—that is the circuits taking power from substations to cars—amounts in a normal interurban proposition to 40% or 50% of the total outlay for electrical apparatus—much the largest single item—and when it is further understood that by raising the voltage the cost of the distributing system may be reduced to a comparatively small fraction of that necessary in the D. C. system, the importance of this matter of abolishing trolley voltage limits may be better realized.

2nd. Necessity for rotary converters done away with. In an interurban system this usually means doing away with an item in first cost of perhaps 10%, as well as avoiding the rotary losses which amount to approximately 10% of the power transmitted.

3rd. The avoidance of skilled attendance in the substations. This avoidance of skilled attendance has the double effect of reducing the yearly cost of operation and of, therefore, enabling feeding points to be established more frequently. This in turn has a marked effect on the cost and losses in the distributing system in favor of the A. C. system.

4th. Avoidance of rheostatic losses at the cars due to the fact that A. C. voltages can be controlled by inexpensive apparatus—a property not possessed by D. C. voltages. It follows that for the rheostats which cause a considerable amount of power loss

in starting, D. C. cars can be substituted, a method of voltage control, thereby avoiding the starting losses.

5th. Electrolysis abolished. To many engineers the gravest problem for the electric railways of the present time to overcome is the damage caused by the electrolysis of th ground return currents. It is a problem, too, that is assuming constantly greater proportions as time goes on and many railway operators would place the fact that this danger is abolished by using alternating current first among the advantages of the system.

6th. The ability to use low voltage motors with a high voltage trolley. The change in voltage between trolley and motors may be accomplished by a transformer carried by the car. Motors are inherently difficult to insulate, therefore the ability to reduce voltage thereon is important in increasing both their life and reliability. A transformer, on the other hand, is a piece of apparatus which is comparatively easy to insulate and therefore can be relied upon to take care of the high voltage strains.

Among the disadvantages that might be cited against the A. C. system are:

1st. Increased weight of equipment. Although the A. C. motors themselves are approximately the same weight as D. C. motors of the same capacity, the regulating devices and the transformer which we deem it advisable to use, make the A. C. equipment somewhat heavier than the equivalent D. C. The total weight of a loaded car, however, when equipped with A. C. apparatus, will not exceed the equivalent D. C. by more than about 5%. The handicap is therefore a small one.

2nd. The increased loss in iron conductors of A. C. over D. C.

The bare statement that a given A. C. of 25 cycles frequency in an iron rail causes five times the loss caused by a D. C. of the same amperage, sounds serious. When we come to consider that a large part of the return current loss occurs in the connecting bonds, in which the A. C. and D. C. loss is practically the same; that the rail loss is usually a small proportion of the total; that with A. C. the voltage will usually be higher and therefore the current less, and that finally with A. C. the distance to return the

current to feeding point is usually much less, the fact of higher A. C. loss loses much of its seriousness.

In the above the writer has tried to give as comprehensively as possible in the space of time occupied a general view of the electric railway situation and the advantages which will accrue to the use of A. C. thereon. The objection may be made that my claims for the A. C. system are not yet established because untried. To this I answer that while the system has not yet been in regular operation in commercial service, both single motors and complete equipments have been operated by the Westinghouse Electric & Mfg. Co. at East Pittsburg, which have convinced the engineers of that Company that they have nothing to fear from the coming commercial development trial. On the strength of this feeling of confidence, four contracts for railways to be equipped with A. C. apparatus have already been taken. The starting of these roads means the beginning of a new era in electric railroading.

DISCUSSION.

VICE PRESIDENT—You have heard these highly interesting papers; they are open for discussion now.

MR. SCOTT—Mr. President, we have heard this evening of the very rapid development there has been during the past twenty years in the methods of passenger transportation. I read not long ago, a book by Mr. Geo. S Morrison, entitled "The New Epoch." It is a book which every engineer should read. It mentions the progress of the human race from its earliest savagery up through various steps to civilization, and notes that there have been different epochs, one of which is marked by the introduction of animal power, a new power brought to aid that of man's muscles. The introduction of the beast of burden marked a new epoch way back in the ages preceding civilization, and yet there was nothing new in the means of passenger transportation for ordinary service such as that through our cities, nothing new from those pre-historic times down until the time within the memory of us all. There was nothing but travel by horseback and by carriage; in Pittsburg there was not even a car on rails until some forty years

ago. The first street car running on rails in Pittsburg was in 1859. The horse-power was continued until along in 1888 or 1889, when the electric motor and the cable road were both introduced; but the cable soon disappeared and the electric road prevailed. That is, the horse had his full sway for unknown ages until within the past twenty years, and then was completely superseded by the electric road within a very few years. Both papers have pointed out that in the electric railway, certain elements have prevailed from the first commercial railways until the present. They have been of one type; there has only been one new element of note, and it has simply been a means to extend the direct current motor system. All the development that there has been, therefore, in the past expansion and extension has been along certain defined lines, and certain limitations have been reached. Now something is presented which is radically new, in that it affords a means of overcoming the limitations which have been encounted; something which is cheaper, that can do things which could not be done before, and yet something which contains those fundamental characteristics in the older system which are so well adapted to the work to be done. Moreover, the new system which seems so well to meet an extending field, gives promise of a new era of development and extension in railway work. It overcomes many of the difficulties which are encountered in the ordinary forms of apparatus for the operation of heavy locomotives, those of the order used in steam railway service. It overcomes the difficulties which are encountered under the present system in the extension of long suburban lines. It overcomes many of the difficulties which are encountered in heavy city work; and it overcomes these difficulties in a way which in general involves a less cost. So that, as far as one can judge from the indications, and indications which are based on apparatus which has been made and tested, we have something now presented to us which opens a new field in railway work.

MR. CLARK—I would like to ask Mr. Lincoln the number of cycles, the number of alternations and the voltage on the new alternating line.

MR. LINCOLN—The standard frequency will be 25 cycles per second, which is a standard which has already been adopted for many power plants. The two frequencies which have commanded the greatest use in this country are 25 cycles for low frequency work and 60 cycles for high frequency work. We have adopted this alternating current system to 25 cycles, the standard low frequency. When we come to the voltage that a customer wants to use. If the customer wants to use a low voltage, as a matter of safety, we can adapt the system to the use of low voltage, but the customer will have to put up with the difficulties which naturally accompany low voltage, such as losses in expenses of the distributing system and the difficulty of collecting the large currents from the working conductor. But in that matter of voltages we have a very flexible system and can adapt it to whatever is desired.

MR. SCHATZ—I think Mr. Lincoln has made it very evident why the alternating current motor is going to come into use very extensively and I think it would interest us all to hear something about that motor. The one thing is how they are going to build those motors in opposite directions so that the cars can be operated in both ways. Probably there are some other little things, too, that might be interesting.

MR. LINCOLN—There is nothing mysterious about this motor. It is simply the direct current motor, as you find it on the cars which it has been attached, made good enough for an alternating current of 25 cycles per second. The principle is exactly the same. The direction of current through any service motor can be reversed and the motor will never know the difference. That is, the trolley may be either passive or negative without distributing the operation of the car. It follows, therefore, that you can run a block with a positive trolley, and the next block with a negative trolley, and the motor will run along all right. If you keep on increasing the frequency of alteration the motor keeps on working the same way. With commercial frequencies certain problems arise due to the circulation of alternating current in the motor. These problems are taken care of by proper design.

Perhaps the question was how the motor was going to be

reversed in direction. Well, just exactly the same as the direct current motor is reversed, that is, by reversing, the direction which the current travels through the field relative to the armature. The alternating current motor is reversed in exactly the same manner as the direct current motor.

VICE PRESIDENT—Gentlemen, any more questions?

MR. RIDINGER—What is the type of controller used?

MR. LINCOLN—The control of the motor is merely a voltage control. There are a number of means which can be applied to changing the voltage at the motors and keeping a constant trolley voltage at the same time. One of them is to bring out loops from the transformer windings, so as to obtain a number of different voltage points and to throw the motors from point to point on the transformer winding, as it is desired to change the voltage. That method has certain constructional objections, such as the breaking of the heavy currents at the points of contact. The method which will probably be very largely used, is to use what we call an induction regulator. That consists of a transformer whose secondary is movable with reference to its primary so that by simply moving the secondary through an arc of -80 degrees, we may get a variation in the voltage applied to the motors. That is the voltage of this induction regulator may be made to add to a certain voltage furnished by the transformer, or it may be made to subtract from this certain fixed voltage; so that the total range of voltage is the certain fixed voltage plus the regulator voltage as a maximum down to the certain fixed voltage minus the regulator voltage as a minimum. And that scheme has the advantage of having no contacts to make or break. The current is not made or broken at any point in the operation of the regulator, so that the difficulty which is now being experienced to a considerable extent with direct current controller apparatus due to the breaking of heavy arcs will be avoided.

MR. RIDINGER—Is that turning done by hand or by means of a motor?

MR. LINCOLN—Usually, on the equipments which we have laid out, the apparatus is so large and so powerful that it cannot very well be done by hand and is done by means of an

air motor. It can be done by means of the electric motor or any other power devices. It might be done by hand, but the amount of power required for the larger systems is too great to allow it to be done conveniently by hand. I may state in that connection that the invariable practice on modern roads is to use air breaks, so that the addition of the air motor for the operation of the controller is not a hardship; it merely means the using of a little more air.

MR. RIDINGER—In case you would furnish a train of several cars with those small motors controlling the regulator, could they be connected in multiples, so that it could be controlled from one point?

MR. LINCOLN—Yes, it could be very easily adapted to this system, so that the movement of a single master-switch will cause all the regulators on this train to move back and forth in unison. The system is easily adapted to the multiple control system.

VICE PRESIDENT—I would like to hear Mr. Storer's side of this question. He is a direct current man and might have some kicks coming on the alternating system.

MR. STORER—One of the places where the alternating current motor is going to help the direct current system, and is going to displace it, is the collection of the current or the power necessary for operating large trains. It is a big question, a serious question, to devise means for collecting the current necessary for operating a heavy train or accelerating it quickly and moving it, when the power is generated at such a low voltage, as we have to do with a direct current system. In the express service, which has been contemplated on the inter-borough system in New York, that is in the sub-way trains, they intend to operate eight-car trains, and each one of these cars is to be equipped with two two-hundred horse-power motors. The power required in accelerating that train will run up to about 5000 amperes. Now that must be collected from a third rail, a section of third rail the length of the train. Ie means that very heavy conductors are required; very goon contacts must be used and if they do not make the most perfect contact, there is going to be serious trouble. That was

found to be the case when the first electric locomotive for the Baltimore tunnel were put into service; there was the greatest difficulty in collecting the current. Sometimes the trolley shoe which they used would become simply welded to the overhead conductor which was in the form of a rail of some description, and it was scarcely possible to pull it away without tearing the whole structure down. Again, in moving the train along, there would simply be an electric shower of fire from the conductor all the time, caused by the heavy current. Now with this alternating current they will probably use a voltage five to six times as great and that means dividing the current by five or six as the case may be, which cuts that difficulty right down.

While I have always been interested in the direct current railway system, since I started in work, I must say that I am very glad to see the alternating current system come along, and I believe that this motor has tremendous possibilities. I can see the difficulties that are in the way of it probably as plainly as any one, but the qualities of the motor are such that they will eventually make it thoroughly successful and it is only necessary to drive out the weak points in it by commercial service for a few months, when no one need be afraid to adopt it, either for city or suburban, interurban or long trunk lines. I think that is the motor which is going to be used for the trunk lines of the future. The time of the steam locomotime is passing. It may be early to say that it will not be in existence in five or ten years, because it will be used for a good many years, but the electric system is bound to displace it in the course of time, and it is the single phase alternating current which is going to do the work.

MR. SCOTT—One of Mr. Storer's figures I have resolved into a different form. He states that a train on the sub-way in New York requires 5,000 amperes. Now 5,000 amperes, at 600 volts, develops a power equivalent to that required for the operation of 60,000 ordinary incandescent lamps. That is the power taken for a single train in starting.

MR. ANDERSON—In view of these speed tests over in Germany, it might be of interest to have these gentlemen explain the difference between that system and this.

MR. LINCOLN—That is one of the systems which are using the induction motor as a motive power instead of any of the types which have been described to-night. I do not know that I can say very much more about it, except that in that system very high voltage motors have been used, motors of the induction type. One of the main disadvantages has been that this type of motor requires three working conductors. In the cuts which appeared in the technical journals, and some of the popular journals, from time to time, you will note that there have been three parallel trolley wires and that the car has carried three trolleys. This is made necessary by the fact that poly-phase induction motors are used on the cars, instead of single-phase or direct current motors, which require only two working conductors, of which the rail may be one, so that the trolleys can be reduced to but one. That motor, as explained in what I read to-night, is inherently a constant speed motor. That is, if the motor has the power of operating the train, for instance, at a hundred miles per hour at its most efficient point, when the train is operating at 50 miles per hour, one-half the normal speed, the efficiency cannot be over 50%. The efficiency cannot be over the ratio of the operating speed to the maximum speed. Is is necessarily less than that. The rest of the power is lost in rheostats, or some other manner; so that that type of motor is not at all adapted, in the estimation of American engineers, to the electric railway operation.

MR. RENSHAW—As I understand these German tests, they were laid out principally for the purpose of investigating high-speed conditions rather than as a test for the particular type of motor that was used in them. Their object was merely to record the power required to drive cars at those high speeds. They used that type of motor because that was the only thing they had available at that time, and I don't think the tests in Germany were laid out to exploit that type of motor at that time. Any type would have done equally well.

VICE PRESIDENT—They made that experiment only with a single car, too; they had no long trains; they did not need so much power. If they have to take off one trolley power for three, four, or more cars, of course more current is consumed

in proportion, and it would be harder on the trolley, and that is where that point comes in that Mr. Storer mentions, that the shoe welded to the conductor.

MR. FLANAGAN—I would like to ask Mr. Lincoln if the starting torque in this alternating current motor is exactly the same as that of the direct current series motor, of the same power, in operating the car in other respects. That is, in two motors of equal power is the starting torque absolutely as great in the alternating current motor as in the direct current?

MR. LINCOLN—The alternating current motor has probably a little advantage in that respect. The alternating current motor is designed to operate at a lower point in the saturation of the iron. The necessary consequence of that is that the torque increases in a faster proportion to the current in-put than it does in the direct current.

MR. PECK—I have had occasion recently to ride over some of the long inter-urban roads in Ohio and Indiana. On those roads the drop in the feeders is so great that at night the lights go almost out; and one rides along for miles without being able to read and hardly to recognize the people across the aisle of the car. With an alternating current system it will be possible to have better lights, for on account of the higher voltages employed on the trolley there will be less loss in the feeders, with correspondingly higher voltage on the lamps, thus adding to the comfort and pleasure of the passengers.

MR. DEWSON—Perhaps Mr. Lincoln would explain to us the difference between the Lamme motor and the Thompson motor, or the other motors that are put up by the different concerns.

MR. LINCOLN—The Lamme motor is the straight series motor. It is the direct current motor, which we are all familiar with, designed so it can be operated on alternating currents. The so-called repulsion motor, which is being exploited by another company, is a motor which is practically the same in its characteristics as the series motor. The difference, however, is that the current is introduced into the revolving element by induction instead of by conduction. Instead of introducing current which flows through the field directly into the arma-

ture, it is introduced into the armature by a transformer action. The field of the motor in that case becomes the primary of the transformer and the rotating armature the secondary. The resultant effect is a motor whose characteristics are practically the same as the Lamme motor. It is rather difficult to go into the details of this matter without raising technical points which are probably more abstruse than the majority here would like to listen to.

MR. WATERS—I would like to ask Mr. Lincoln if these alternating current motors can be used satisfactorily for short distances over the present direct current system. Were any running over a direct current line for a short distance in the city?

MR. LINCOLN—The motor being practically a direct current motor, can, of course, be used on direct currents. A difficulty when operating an alternating car on direct currents comes in the controlling mechanism. Such control as gives the best results when operating as an alternating current car cannot be used when operating as a direct current car. Another difficulty which arises is, that in order to make a successful alternating current motor, the voltage which can be applied is limited to a point which is below the voltage of the direct current motor; so that the motors, if operated on direct currents, have to be operated in series. There are certain disadvantages to operating motors constantly in series, which would naturally accrue to the alternating motors when operating on direct currents. It is perfectly possible to operate these motors on direct currents, but it makes a somewhat complicated arrangement.

MR. WATERS—Another question: Is the trolley on the car such that it could be used with the low voltage in the city and the high voltage in the country, in the suburban service?

MR. LINCOLN—Yes, that is perfectly feasible. In one of the contracts for a road which my company has undertaken we are required to run at a trolley voltage of 3,000 volts alternating part of the way, part of the way at a trolley voltage of 500 volts, alternating, and part of the way at a trolley voltage of 550 volts direct. That will show you the flexibility of the system. Our equipments are being made to operate under those three conditions.

MR. ANDERSON—One more question, Mr. President: If this motor is run as a distinctive motor, what will the weight be as compared with the present locomotive in tonnage? Would it be run as a distinctive unit, separate from the cars, or will they become a part of the car the same as the street-car system?

MR. LINCOLN—Well, that is a question which is entirely separate from the motor. Either can be done. We can either use the locomotive or put the motors under the live load and use the live load for traction purposes. It depends upon the result that is to be accomplished. For freight service probably the locomotive will be used; but in attacking the ordinary inter-urban railway problem that we get, each car is made a motor car, as a rule.

MR. ANDERSON—The point I wanted to get at was, if you run it as a locomotive what will be the tonnage as compared with the present locomotive tonnage?

MR. LINCOLN—Compared to steam it would be considerably less, for two reasons. One is you don't have a tank for water and coal, which simply is an addition of weight not necessary in the electric locomotive, and the other is that the torque, at all points of the revolution of drivers, is constant, whereas in the ordinary locomotive there are points where the torque is considerably higher than at other points. That means that the torque at the maximum torque of the revolution cannot exceed the point of slippage, whereas on the motor we can run the torque up at all points of the revolution to the point of slippage.

MR. STORER—There is one other point that may be mentioned in connection with that single-phase motor. That is that it is more nearly full proof the handling of the motor in our city cars; for instance, if a man only uses one notch on his trolley, and that is the last one, he can jerk the car from under the passengers entirely and the current which will come through there will not be anything nearly as great as it would be with a corresponding direct current motor. It will carry probably as much power as the wheels can hold down comfortably, but it can't jerk the car as the direct current motor

does. It is going to be much better and safer in that respect.

MR. RIDINGER—Before adjourning I move that the Society extend to Mr. Renshaw and Mr. Lincoln a vote of thanks for their very valuable papers.

MR. SMYTHE—Before that motion is put before the house there is just one question I would like to ask and that is in regard to the overhead construction. Relative to the new system, what effect is that going to have in regard to the trolley and feeder systems, as we have them now under the direct current system? Is it going to curtail the circular millage of the feeders, as we now use them, for a five to six hundred-volt direct current?

MR. LINCOLN—That reduction of the amount of distributing copper is one of the main points of advantage of the alternating current system. The reduction may be obtained either by raising the voltage or by placing the feeding points of the system closer together. As a rule the systems which we have figured upon, we have estimated upon simply the trolley wire alone for the secondary distributing circuit. Uusually mechanical considerations do not allow of the use of less than a certain size trolley, possibly No. 00, and that amount of copper, by spacing the sub-stations at conveniently frequent intervals, is entirely sufficient, and usually entails a much less loss than occurs in the present direct current system. That means the elimination of the feeder systems, as they exist today. It is cheaper to put in transformers, as a rule, than to put up copper.

VICE PRESIDENT—Now the motion is that we express our thanks for these highly interesting papers, which were so well discussed, and surely will be read in the proceedings with much satisfaction. (Motion carried.) Mr. Scott will address you on something which will interest you. Mr. Scott has the floor.

MR. SCOTT—Mr. President, this has been to me a very notable day, and I want to take this occasion, before this society, to make a public announcement of something which is being made public to-day and will probably appear in the papers tomorrow.

If I may be allowed to reminesce, and be pardoned if some of my statements are somewhat personal, I will ask your forbearance for a moment. Some two years ago I became President of this Society and I became very much interested in the Society as an organization of engineers, and I begun to see something new in an engineering society; in it, as a force among engineers, and engineers as a force in modern society. I was called upon the next fall to become president of the American Institute of Engineers. I came to that work fresh from the inspiration I had gained from the efforts and cooperation with you in this Society, and I entered heartily into its work and its development. It is an organization of the engineers who have been fundamental in producing such marvelous results as those we have heard this evening, which have become of such great prominence and importance during the past decade.

Within a few months I was privileged to attend the John Fritz dinner, the anniversary occasion of the venerable John Fritz, following his 80th birthday, many of his friends having joined together and raised a fund to establish the John Fritz medal, to be awarded yearly. That was a notable dinner of some four or five hundred. The medal and the dinner were gotten up by committees from the four national engineering societies, and I became in this way better acquainted with the other societies, and it seemed to me there was a great possibility in what these societies could do in working together. About this same time, I think it was the same week, a Building Committee of the Institute met with the Board of Directors and discussed ways and means. There was a suggestion that we ought to have a joint building with other societies; but that was looked upon as being in theory very good, but really quite impracticable. But I cherished the ideal and hoped that a time would come when something definite could be accomplished. I built air castles along this line and talked with some friends about it and suggested it at the 25th anniversary of the Engineers' Club at Philadelphia, at which I was priveleged to present some ideas on the "Engineer of the 20th Century," with which many of you are more or less familiar.

Some two months after that the American Institute had an annual dinner, at which Mr. Carnegie was the guest of honor, and I made some remarks in which I suggested the line of thought which I have just introduced here; the importance of the modern engineer, the great results which come through co-operation, the great benefit it would be to the engineering profession to have closer co-operation among its different branches, and the advantage it would be to have a building which would be a material basis for the things which engineers want to do. That idea appealed to Mr. Carnegie, and the next day he sent for me and Mr. C. W. Rice, a member of the Institute, who was at that time a resident of Pittsburg and a member of this society. We called on Mr. Carnegie and he said he had been interested in the idea of co-operation among engineers and wanted to know what our ideas were in the way of a building. The matter was discussed informally, and he said, "Well, go and get your plans and when you have some plans come back and I will be glad to see you again." So we got together with some of the friends. We went first to the treasurer, and one of the leading men of the John Fritz dinner committee, and as a result we got together members of the different organizations; we had a meeting the next day and we appointed a sub-committee which waited on Mr. Carnegie, and on Saturday of the same week he indited the letter with which you are all familiar, presenting to the four national engineering societies and the Engineers' Club the sum of $1,000,000.00 for the building. You know the history during the last year: all the societies, except one, took favorable action at once, but the other took the matter under consideration and finally determined not to accept. The whole scheme then seemed to have about reached its termination, for in Mr. Carnegie's mind the great idea was co-operation, the bringing together of the branches of the engineering profession and putting them on a new basis for the future.

Mr. Carnegie has had a far-reaching ideal and the essence of the schemes seemed to be gone when the thing upon which he had depended so much, a hearty co-operation, was found to be wanting.

A week ago to-day a committee waited upon him, a committee of the concurring societies, as he asked what we wanted to do and we said, "Go ahead." He questioned our ability to go ahead without the remaining society and said he would like a financial statement and general resume of the situation. Meetings of the board of directors of the societies were called and resolutions re-affirming previous action were passed. Letters were received from many of the minor engineering societies indicating that they would like to have accomodations in the building. The whole matter was again presented to Mr. Carnegie on last Saturday afternoon, together with the membership curves. The three societies of Mechanical, Mining and Electrical Engineers have a membership ranging from 2,700 to 3,500. Their present available assets amount to $160,000.00 and the annual income of each of the three societies is very close to $45,000.00. The membership curve is such that if there are as many new members in the next three years as there have been in the last three, the dues from the increased membership would be enough to maintain the running expenses of the building. These matters were presented to Mr. Carnegie and he was very glad to see that the societies were willing and able and ready to take up and go forward with this great work, and he said that on Monday he would write a letter; and at the suggestion of the committee he would put that letter in the original form and transmit it to us. The original form of the letter, with one slight change, is as follows (reads letter) and that is the form in which he said he would put it. I have a telegram reading, "Have received the letter from Mr. Carnegie, and you may publish the news." Signed "T. C. Martin," one of the committee. The letter, then, will now presumably read as follows: (Reads letter.) Now a settled fact. (Applause.)

VICE PRESIDENT—That is very handsome, of course. It would be nice, now, if our turn would come and Mr. Carnegie would think of us. I suppose we are not called upon to take action on that matter; or do you think so?

MR. SCOTT—I move that the Secretary be authorized to send to Mr. Carnegie the following resolution: "The Engineers'

Society of Western Pennsylvania expresses its high appreciation of the gift of $1,000,000.00 which has been made by you to three of our national engineering societies, which have many members in Pittsburg."

Motion carried and Secretary instructed to wire Mr. Carnegie.

Motion to adjourn. Carried.

C. W. RIDINGER,
Secretary.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held at the Society's room, 410 Penn Ave., Pittsburg, Tuesday, March 22, 1904.

Section called to order by the Chairman, Frans Engstrom, at 8:20 P.M., 52 members and visitors being present.

Minutes of the previous meeting were read and approved.

Subject selected for discussion at the next meeting, April 26, Coffer-dam Construction.

The Chairman announced the standing committees for the year as follows:

Timber Construction—E. G. Ericson, W. M. Judd, W. C. Hawley.

Masonry Construction—F. Z. Schellenberg, A. G. Shaw, B. V. Sommerville.

Rolling-Mill Practice—W. L. Shaw, Harry J. Lewis.

Railroad Bridge Construction—E. K. Morse, F. A. Glafey.

Highway Bridge Construction—C. M. Canady, Chas. Davis.

Mill Building Construction—P. Brynn, A. E. Duckham.

Office Building Construction—S. J. Affelder, Chas. Worthington.

Concrete-Steel Construction—Robert A. Cummings, Emil Swensson, W. G. Wilkins.

Shop Practice—J. H. Thompson, H. Bainbridge.

The paper of the evening. "Blast-Furnace Slag as a Structural Material" was read by Joseph A. Shinn.

The discussion was participated in by Morris Knowles, A. D. Wilkins, Ralph Crooker, Frans Engerstrom, H. C. Babbitt, and the author.

On motion a vote of thanks was tendered the author, Mr. Joseph A. Shinn.

On motion Section adjourned.

WILLIS WHITED,
Sec. Struc. Sect.

BLAST FURNACE SLAG AS A STRUCTURAL MATERIAL.

BY MR. JOS. A. SHINN.

During the year 1903 there was produced in the United States upwards of 10,000,000 gross tons of blast furnace slag, a quantity sufficient to cover 2,000 acres, or more than 3 square miles, to the average depth of three feet, if in the form of broken stone.

Of this quantity, a few hundred tons were used in the manufacture of slag wool; less than 75,000 tons in the manufacture of Portland and Pozzuolani cements, and possibly 1,000,000 tons as substitutes for broken stone, gravel for roofing, etc.

The balance, or more than 9,000,000 tons, was deposited in low ground or unsightly heaps near the furnaces, or was used by railroads for embankments and ballast.

Of the total quantity produced, 45% was produced in the State of Pennsylvania, and 23½%, or more than 6,000 tons per day for every day in the year, was produced in Allegheny county. At no other place in the world is an equal quantity produced in so limited an area.

The whole of this latter quantity could be utilized in construction with a gain in quality of structures produced, or at a saving of cost, or both.

As early as 1770, granulated slag was recognized as furnishing a material of very superior quality for the making of mortar as compared with common sand.

From about 1820 to 1870, numerous attempts were made in England to utilize the slag commercially, by casting it into blocks for road paving, but with indifferent success.

In 1840, Edward Parry, of Wales, commenced the manufacture of slag wool, but it was not until its manufacture by Krupp, at Essen, and Luurman, at Georgemarienhütte, in

Hanover, about 1875, that it became a recognized commercial product.

In 1870, Mr. Fritz Luurman, a well-known furnace engineer, began the manufacture of bricks at Osnabrück, Germany, using 90% to 94% of granulated slag, and 6% to 10% of common lime. Of these bricks, Mr. Luurman says: "They are adapted to all kinds of sub-aqueous and subterranean foundation work, as well as to super-structure, and their refractory qualities make them suitable for the linings of lime kilns, and boiler furnace stacks, and for hot blast stoves.

In 1873, the Tees Slag Co., of Middlesboro, England, began the manufacture of these bricks, but instead of using lime for the matrix, they prepared a crude slag cement, made by the wet process consisting of 70% granulated slag, 15% lime hydrate, and 15% of calcined iron ore, ground to about 60 mesh, and used 15% of this mixture with 85% granulated slag in making bricks, making the lime addition but 2.15% of the whole.

They also executed a number of engineering works in concrete, using this crude cement for the matrix and broken hard slag for the aggregate, among the early structures being a six-story mill building, the foundation for a 100 ton steam hammer, arches under a large brick station and platform for the London & Great Eastern Railroad, and a number of foundations for rolling mill machinery.

The manufacture of slag bricks is now carried on in all of the iron producing districts of Europe. This industry, together with cement and aggregates, comsumes a large part of the slag produced.

In 1883, a patent was issued to Bosse & Walters, of Germany, for a cement consisting of 85% granulated slag and 15% common lime hydrate, ground together to a fineness of 90%, through a 200 mesh screen.

The term Pozzuolani cement has been given to this product because of the similarity of physical appearance and hydraulic action of Pozzuolani and furnace slag.

Pozzuolani is of volcanic origin, and was produced by the molten lava coming in contact with water during its eruption.

Its chemical constituents are mainly silica, alumina and iron, lime being present usually to the extent of 3% and seldom over 6%.

Pliny and Vitruvius mention that during the time of the Roman Empire, Pozzuolani was used in place of sand, in the construction of some of the viaducts and aquaducts which have stood for centuries and parts of which are still in existence, monuments of engineering skill.* "At Pozzuola, a breakwater, consisting of 24 arches, was constructed of brick, faced with stone, the mortar for which consisted of Pozzuolani and common lime. Although constructed more than 1800 years ago, 13 of these arches are still standing above water."

As in slag, the silica in Pozzuolani is soluble in the presence of lime, and to this fact is due its hydraulic quality. In modern times hydraulic cement has been made by grinding Pozzuolani and mixing it with lime hydrate in the same manner as is now done for slag cement.

For many years it has been the practice of some of the manufacturers of Portland cement, in Germany, whose works were located near blast furnaces, to mix a quantity of granulated slag with their cement. It was claimed that it not only cheapened the product, but that it materially improved the quality of the cement. The latter claim was denied by those not using slag and resulted in the adoption of a definition for Portland cement by the Verein Deutscher Portland cement Werke, which excluded from membership those using slag.

With the further development of the Portland cement industry, slag was in some works substituted for marl and limestone, in the manufacture of portland cement, and was found to be capable of producing a stronger cement than the latter materials. The term "Eisen Portland cement" was applied to the new product.

This was followed by the organization of the Verein Deutscher Eisen Portlandcement Werke, embracing those who made Portland cement from slag, and those who mixed slag with either kind of Portland cement. It is claimed by the latter association,

*American Encyclopedia.

First. That Portland cement made from slag is stronger than when made from marl or limestone; and

Second. That the addition of 30% of granulated slag to any Portland cement adds materially to its strength while reducing its cost.

These claims have received recognition by such authorities at Tetmajer, of Zurich; Michaelis, of Berlin; Le Chaterlier, of Paris; Passow, of Hamburg, and Mr. J. H. Stead, member of the British Institution of Civil Engineers, of Middlesboro, England. And in the report made to the Swiss Government, by Dr. L. Tetmajer, Director of Tests of Building Materials at the Swiss Polytechnic School of Zurich, he says of slag Pozzuolani cement: "I consider slag cement a binding material, par excellence."

Literally interpreted, it was intended to convey the opinion that it was equal to the best Portland cement, if, as previously stated by him, it was supplied with a sufficient quantity of water during the early period of induration, it requiring more water than Portland cement at that time.

Regarding the theory of the deleterious influence of sulphur in slag cement, Dr. Tetmajer says: "I have yet to learn of an authenticated instance of injury to a structure in slag cement, due to the presence of sulphur."

"Stahl and Eisen" for March 15, 1903, contains a paper by Jantzen, Director of Works at Wetzler, read before the Union for the Advancement of Industrial Activity, February 2, 1903, in which he gives the following comparative tests:

TABLE I.

All briquettes 1 part cement, 3 parts standard sand.
Tensile strength lbs. per sq. inch.

	3 days.	7 days.	14 days.	3 mos.
Portland—pure, in water	202	294	333	425
Portland—70%, fine ground slag, 30%, in water	182	284	384	524
Gain %			14.7	23.5
Portland—pure, in air	196	302	376	490
Portland—70%, fine ground slag, 30%, in air	253	364	496	602
Gain %	30.0	20.7	32.0	23.0

*Portland—pure, in water	217	193	214	333
Portland—50%, fine ground slag, 50%, in water	215	335	386	505
Gain %		74.0	80.0	57.6
*Portland—pure, in air	275	369	373	364
Portland—50%, fine ground slag, 50%, in air	348	335	416	516
Gain %	26.5		11.7	41.7

A more marked illustration of the effect of aiding slag to Portland cement is furnished by the following comparative tests of an under-burned Portland cement, and the same with the addition of 50% slag:

	3 days.	7 days.	28 days.
Under-burned Portland 1, sand 3	0	60	109
Same, with 50% slag 1, sand 3	107	206	373
Gain %		340.0	242.0

These results would indicate that the cement was not burned at a heat greater than that required for natural cement, the strength at 28 days being about that of such cements, while the strength of the slag mixture is equal to that of a good Portland cement.

The average of the tests made at these works for two years, the product being a Portland cement made from slag, with the addition of 30% of granulate, is as follows:

Tensile strength per sq. in. cement 1, sand 3.

	In water.			In air.		
	3 days.	7 days.	28 days.	3 days.	7 days.	28 days.
1901	172	219	314	207	295	359
1902	205	244	335	238	321	408

Fine ground granulate made into a mortar with 30% of a 4.6% soda solution, and without any lime, set in the air for 7 days, and immersed in a 3% soda solution for 35 days, give a tensile strength of 285 pounds.

Fine ground granulate made into blocks and set under pressure without lime or other chemical additions, gave crushing strength of 560 to 700 pounds per square inch, at 6 months.

"Stahl & Eisen," for August 1, 1903, contains a paper read by Dr. Passow, of Hamburg, before the International Congress of Applied Chemistry, at Berlin, in which he gives the following comparative tests:

*Contained excess of free lime, probably due to under burning.

TABLE II.

All briquetes 1 part cement, 3 parts standard sand.

Cements.	Hardening.	Age.	Tensile. lbs.	Tensile. Gain %	Crushing. lbs.	Crushing. Gain %
Common Portland	in water	7 days	230		2172	
Eisen Portland	in water	7 days	227		2442	12.5
Eisen Portland 70%, slag granulate 30%	in water	7 days	272	18.0	2868	32.0
Common Portland	in air	7 days	281		2116	
Eisen Portland	in air	7 days	360	28.0	2882	36.0
Eisen Portland 70%, slag granulate 30%	in air	7 days	376	33.8	3394	60.0
Common Portland	in water	28 days	281		2563	
Eisen Portland	in water	28 days	312	11.0	3646	42.0
Eisen Portland 70%, slag granulate 30%	in water	28 days	359	28.0	3723	45.7
Common Portland	in air	28 days	419		3072	
Eisen Portland	in air	28 days	462	11.0	3234	5.3
Eisen Portland, 70%, slag granulate 30%	in air	28 days	378	10.0	4083	32.6
Eisen Portland	in water	7 days	305	32.5	2706	24.6
Eisen Portland 54%, slag granulate 46%	in water	7 days	284	23.5	2422	11.5
Eisen Portland	in air	7 days	344	22.5	2847	34.5
Eisen Portland, 54%, slag granulate 46%	in air	7 days	299	6.4	2596	22.6
Eisen Portland	in water	28 days	457	63.0	4471	74.5
Eisen Portland 54%, slag granulate 46%	in water	28 days	493	75.7	4218	64.6
Eisen Portland	in air	28 days	534	27.4	4164	52.1
Eisen Portland 54%, slag granulate 46%	in air	28 days	429	2.4	3780	23.1

Gain % shown is that compared with common Portland cement same age and condition.

The additions of slag granulate were ground with the clinker.

Table III. shows comparative tests of common Portland, Eisen (slag) Portland, Portland mixed with fine ground slag granulate and slag (Puzzuolani) cements.

TABLE III.

All briquettes 1 cement, 3 sand; in air 1 day, balance of time in water.

	Tensile.				Lbs. per square inch.			
							Crushing.	
No.	7 days.	28 days.	3 mo.	1 year.	7 days.	28 days.	3 mo.	1 year.
1	230	281			2172	2563		
2	302	492	472	560	2030	3030	3770	5026
3	230	322	406	490	2002	2926	3654	5068
4	249	321						
5	227	312			2442	3646		
6	305	457			2706	4471		
7	272	359			2868	3723		
8	284	493			2422	4218		
9	230	370	462	560	1764	3030	4116	4690
10	196	356	434	518	1490	3052	4200	4872

1. Common Portland from Table II.

2. Common Portland. Average of ten series of tests giving more than 224 lbs. each, at seven days, from table including 36 series of 20 standard European Cements, by Tetmajer.

3. Average of the whole 36 series of tests.

4. Average of 30 briquettes each, of 8 standard brands of American Portland cement. Tests by Pittsburgh Testing Labratory, Ltd.

5. Eisen Portland, from Table II., first series.

6. Eisen Portland, from Table II., second series.

7. Eisen Portland, with 30% slag, from Table II., first series.

8. Eisen Portland, with 46% slag, from Table II., second series.

9. Slag Pozzuolani cement. Average of nine series of tests, giving more than 224 lbs. each, at seven days, from table including 19 series from 9 European Slag Cement Works, by Tetmajer.

10. Average of the whole 19 series.

For the manufacture of slag, Pozzuolani cement, all authorities agree that the slag should be highly basic, the furnace working hot, and that the quicker the slag is quenched the better the cement.

The ordinary method of granulation is by running the molten slag into a tank of water, in conection with a stream

of water under low pressure (usually jacket water) for the purpose of breaking up the mass and supplying the loss due to evaporation.

The chemical analysis of granulate differs but slightly from that of air cooled slag, usually showing a slight loss of sulphur. According to Tetmajer, the physical condition undergoes a marked change, the elements being more or less dissociated according to the rapidity of quenching, and the silica being rendered quite soluable in the presence of free lime. Le Chatelier also discovered that granulate contains a large proportion of latent heat, while air cooled slag contains very little, this result also depending on rapid quenching.

Experiments made by the writer for the purpose of producing a material from furnace slag for use as a substitute for river or bank sand, for mortar and other purposes, without the necessity of a second operation of crushing or grinding resulted in a granulate of greater weight and density than common granulate, finer and more uniform in size, with a well defined granular structure, and owing to the more rapid quenching capable of producing a mortar of greater strength when combined with either cement or lime, because of its greater hydraulic energy.

To this material I have applied the term "slag sand," in contradistinction to that of slag granulate as applied to the lighter and less hydraulic form.

It is produced by projecting two jets of water under a pressure of 40 to 80 pounds per square inch, according to the size of the slag stream, in the line of the flowing molten slag.

The jets now used are 10″ wide, and $\frac{1}{8}$″ thick: one being placed immediately below and on a line with the runner spout and the other above and at nearly a right angle to the first.

The slag flows from the runner spout and falls on the lower jet of water, but does not penetrate it, owing to the high pressure, while the velocity of the water causes the slag to draw into a thin sheet. The upper jet striking this sheet a few inches from the end of the runner spout, causes its thorough disintegration and instant quenching, and it falls into the tank below.

The following comparative tests of river and slag sand, with various cements and lime, show the superior qualities of slag sand for mortar purposes.

TABLE IV.

Tests made by the Pittsburgh Testing Laboratory Limited. All the Mortars contained three parts of sand to one part cementing material.

Cements.	Sands.	Tensile strength lbs. per sq. in. 7 days.	14 days.	28 days.	3 mos.
Portland	River	252	324	390	435
	Slag	278	375	484	594
Comparative gain, lbs		26	51	94	159
Comparative gain, per cent		10.3	15.8	24	36.5
Louisville	River	44	47	50	120
	Slag	59	61	63	145
Comparative gain, lbs		15	14	13	25
Comparative gain, per cent		34	30	26	21
Puzzuolani	River	153	192	222	332
Slag cement	Slag	174	271	295	479
Comparative gain, lbs		21	79	73	147
Comparative gain, per cent		15.7	41	32.5	44.3
Mason's mortar: soft					
Lime	River	0	0	17	24
	Slag	...	90	131	163
Comparative gain, lbs		...	...	114	139
Comparative gain, per cent		...	...	771	580
Concrete mortar: stiff.					
Lime	River	...	...	34	47
	Slag	...	142	160	255
Comparative gain, lbs		...	...	126	208
Comparative gain, per cent		...	...	371	441

The tests show the following results:

First—That Louisville Cement with slag sand is 18 per cent. stronger at seven (7) days than with river sand at 28 days.

Second—That soft lime mortar with slag sand is 80 per cent. stronger at 14 days and 162 per cent. stronger at 28 days, than Louisville cement with river sand at 28 days.

Third—That stiff lime mortar is 184 per cent. stronger at 14 days and 220 per cent. stronger at 28 days than Louisville cement with river sand at 28 days.

Fourth—That soft lime mortar with slag sand is 36 per cent. stronger and stiff lime mortar with slag sand is 112 per cent. stronger than Louisville cement and river sand at 3 months.

Common granulate with lime, gives tensile strength at 28 days of 60 pounds as soft mortar, and 90 pounds as stiff mortar.

When common sand is used in mortar or concrete, the strength is dependent wholly upon the adhesion of the cement. The sand is absolutely inert.

When slag sand is used the sand contributes materially to the chemical reaction resulting in cohesion of the materials.

For the purpose of obtaining a more accurate comparison of the hydraulic qualities of slag granulate and slag sand, a quantity of each from the same furnace and cast, was made into slag Pozzuolani cement with 15 per cent. of lime.

TABLE V.

Tensile Strength per Square Inch.

	Slag Pozzuolani Cement, Neat.			1: 3 Sand.		
	Slag Granulate.	Slag Sand.	Gain %	Slag Granulate.	Slag Sand.	Gain %
7 days	335	378	6.5	68	82	35.3
14 days	358	479	33.8	82	125	52.4
28 days	409	505	23.5	106	170	60.4
3 months	508	645	27.0	160	217	36.0
6 months	469	629	34.1	156	275	76.3
Average gain %			25.5			54.0

No effort was made to determine the quality of the lime used nor the best proportion for obtaining high absolute tests but the comparison justifies the theory that rapid quenching improves the hydraulic quality of slag.

TABLE VI.

Analysis of lime used in Table V.

Gran.	Air Cooled.	Granulate.	Sand.
Silica	33.30	33.08	33.60
Alumina and iron	14.78	14.80	14.82
Lime	50.22	50.10	50.25
Sulphur	1.48	1.41	1.10
	99.78	99.39	99.77
Sulphur as sulphide		1.12	.88
Sulphur as sulphate		.29	.22

While the granulate shows a loss of sulphur of .07%, the slag sand shows a loss of .38%, or 25.7% of the total sulphur.

Reference has been made to the setting of fine ground slag granulate under pressure and without addition of either lime or other chemicals. Slag sand possesses this quality in a high degree without being ground, as is illustrated by the following practical application, a sample of which is here shown.

One to two inches of slag sand was used for the bedding of brick paving on foundation of 6" broken stone and 2" to 3" of gravel. At the end of four and one-half weeks, a section of this paving was removed for the purpose of putting in water pipes, and it was found that the sand had set into a sheet of moderately strong concrete with the gravel adhering to the under surface. A piece of this about 1 foot square was obtained by the writer, and being kept damp, has continued to harden. Owing to its sharpness, slag sand under pressure will not flow when enther dry or super-saturated, and when set contributes materially to the stability of such paving.

The opposition encountered in Germany and France by the manufacturers of the various slag cements has resulted in the production of a very considerable literature on the general subject of slag utilization, and with the further result that the opposition has been placed upon the defensive.

Unfortunately for us, the literature of slag is almost wholly in the German and French languages.

While the Portland cement industry had its inception and early development in England, it is to Germany that we are indebted for its improvement in strength and reliability, and a thorough knowledge of its chemical action. That slag has been in use for more than 30 years in a country where cheapness is not a first consideration in engineering construction, but where ultimate economy is a necessity, and that it has made steady progress until it has been recognized by the best authorities as not only equal to the best material for particular structural uses, but as having no equal as a binding material in concrete and mortar, its use being not only permitted but specified in important state, municipal and other engineering works, is a sufficient guarantee of its strength and stability to

warrant the American engineer in encouraging its adoption here.

The probable effects of the sulphur contained in slag, when the latter is used in any of its forms in concrete-steel construction, is answered in "Notes from Report, No. IX. of Insurance Engineering Experiment Station, Boston, Mass."

"The results of the test which were carried out under various conditions, lead to the conclusion that structural steel if encased in a sound sheet of good concrete, is safe from corrosion for a very long period; longer than the changes in our cities will allow any building to remain. It is a necessity, however, to be sure that the steel is properly encased in the concrete, and because of the difficulty in getting sound work, many engineers will not use concrete. This is especially true of cinder concrete in which the porous nature of the cinder has led to much dry concrete and many voids and much corrosion. There can be no question that cinder concrete has rusted great quantities of steel, not because of its sulphur content, the danger from which is a myth, but because it was too dry. If cinder concrete be mixed wet, and well mixed, it may be trusted as much as stone concrete, so far as corrosion is concerned."

I hold that the same is true of slag concrete. Oxidation of the sulphur in the slag and consequent corrosion of the steel from that cause, cannot take place if the concrete is sufficiently solid to exclude the air.

The converse of this proposition is true, that no matter what materials enter into the concrete, if it is not made sufficiently solid to practically exclude the air, corrosion of the steel will inevitably result.

Experiments and developments in the utilization of slag have progressed along the same lines in the United States as in Europe, with the exception of brick making.

The manufacture of slag wool was commenced by Alexander D. Elbers, in New Jersey, about 25 years ago, and is now carried on commercially in a number of places.

The Illinois Steel Co. has been making slag Pozzuolani cement since 1893, and it is now being made at Sparrows Point, Md., Youngstown, O., and at other places.

The Illinois Steel Co. has also been making slag Portland cement since 1899, and its manufacture was carried on, in a

small way, at the Clinton furnace in this city for several years, but has now been abandoned.

The only attempt to make slag bricks in this country, of which I have knowledge, was by the Brier Hill Iron and Coal Co., at Youngstown, Ohio, in 1902, when they erected an experimental plant and produced about 50,000 like the sample here shown.

At Freesland, near Philadelphia, and at Reading, Pa., there are plants for crushing and sizing hard slag for concrete aggregate, roofing, etc.

In the east, gravel for tar roofing has been almost wholly superseded by crushed slag, and it is being shipped from Philadelphia and Reading to Pittsburg, at a cost for freight of more than $2 per ton. Carrying coals to New Castle is a reasonable proposition compared with this.

As a rule limestone is to be preferred for aggregate in foundations, retaining walls, etc., but in concrete floors and walls and other places where weight is an objection, and fire-proof qualities desirable, crushed hard slag is much to be preferred.

If blast furnace slag were used for all purposes, for which it is economical as being better adapted or cheaper than like materials now in use, the order of quantities used would be for the purposes as follows:

First. As sand for concrete street paving, building block, rubble masonry.

Second. In brick; for foundations; superstructure and refractory purposes.

Third. As aggregate for concrete; roofing, etc.

Fourth. In the manufacture of Portland cement.

Fifth. In the manufacture of Pozzuolani cement.

Sixth. In the manufacture of slag wool for non-conducting purposes.

The value of the products for a unit of weight would be in about the reverse of this order.

DISCUSSION.

MORRIS KNOWLES.—I have been much interested in this paper and think the subject of which it treats is worthy of careful study and investigation and the author deserves our

thanks for the patience and care he has shown in placing before us so much of the available data on the subject.

A few questions come to mind:

1. Is the fact, taken from the report of the Insurance Engineering Experiment Station, that the sulphur in the cinder aggregate used in concrete does not attack steel, any proof that slag aggregate will not do so? Is not the amount of sulphur in slag greater than in cinders or ashes? and does not the water in the concrete increase its effect?

2. The experiments quoted by the author seem to show that slag sand or aggregate increases the strength of Portland cement mortar or concrete. Is that increase permanent, or is it limited to a few months?

3. Would a concrete wall containing slag, either in the mortar or in aggregate and exposed to the hot sun require anything more than the ordinary sprinkling over once or twice a week?

4. What is the cost of slag sand or aggregate as compared with river or bank sand and gravel?

MR. SHINN—I will answer these questions in order.

1. The cinders and ashes from anthracite coal, such as is used in New England, contains a larger percentage of sulphur, either free or in the form of sulphides, than slag made from Lake Superior ores and Connellsville coke. It is a well-known fact that iron will not rust in a basic medium and, as Portland cement as well as slag, is essentially basic at ordinary temperatures notwithstanding the small amount of sulphur that it commonly contains, no fear need be entertained as to any corrosion of steel due to any water or sulphides that the slag or cement is likely to contain, provided there is a continuous coating of cement mortar in contact with the steel. At the proper time I will read you a letter bearing on this matter.

2. The experience of thirty years in Europe shows conclusively that the increase in strength is permanent.

3. Tetmayer's opinion, which I have quoted, was evidently intended to cover such an application of water as would usually be practicable. Personally, I would not recommend it in any light structure exposed to the hot sun.

4. Where river sand can be delivered by barge it is the cheaper material, but where it must be delivered by rail the slag is cheaper. On an average the prices are about the same.

MR. JOHNSON.—The author of this paper by his painstaking research into the history of the use of furnace slag in the manufacture of cement, and collecting the scattered literature on the subject, has contributed to our Proceedings a paper of more than ordinary merit and value. He has not only brought to our notice a subject not heretofore familiar to the profession at large, and told us nearly all that he has done and knows about it, but has supplied us with full references to publications where we may learn all that others know. The subject matter is so far new to us, that the paper takes on somewhat the nature of original research, and places it in the list of high-class papers which are a contribution to knowledge, put life and "esprit" into the Society, and add value to our publication.

We are more ready to accept new processes and new materials, and the laws governing their behavior under given condials and the laws governing their behavior under given conditions. From this point of view I regret that the author did not enlarge more fully on the reactions which occur between the lime and the silica of the slag, when brought together in the mortar, as contrasted with the reactions occurring in other mortars.

In common lime and sand mortar, the silica of the sand is not soluble in lime, and no reaction between the two takes place. The mortar becomes indurated by slow absorption of carbonic acid from the atmosphere, forming a carbonate of lime. This process is very slow and such mortars do not attain their full hardness for many decades; in fact it is doubtful if the lime is fully carbonated under several centuries. Exposure to fire recalcines the carbonate, expelling the carbonic acid, and reducing the lime to the caustic condition.

Hydraulic and Portland cement mortars harden by hydrated crystalization, the transformation which takes place being structural rather than chemical.

With the lime and slag mortar, induration is the result of a chemical reaction, by which the lime and silica enter into direct combination, forming silicate of lime. This fact was demon-

strated to my satisfaction several months ago, where Mr. Shinn exhibited to me a briquet which had been kept in a gas fire for about an hour and then plunged into cold water. It showed no sign of calcination.

Silicate of lime is indestructible by ordinary atmospheric influences, and is not affected by heat. It is the material with which nature has cemented the grains of sand in our best and most durable sandstones. We have therefore every reason to anticipate the most lasting results from such a mortar, unless other elements in the slag should prove to be sources of failure.

What reactions take place in the presence of the cements, natural and Portland, some of our chemist members will have to explain. The base of the cements is silicate of alumina, and I do not understand how the presence of more silica, even in a soluble form, can bring about a reaction, unless it may be that there is a general breaking up and new arrangements of atoms in new proportions. To the extent that free lime may be present, it is easy to understand how the conversion of that into a silicate will improve the quality of the resultant mortar, adding to its strength and permanence.

But does or does not the influence of the slag extend beyond this neutralizing of the free lime? This is an interesting question which some of our young chemists might follow up with interest and profit.

E. K. Morse.—In every one of my specifications for Masonry Construction these words are found: "Clean Allegheny River sand and gravel, free from all foreign or detrimental substances." Why Allegheny River and not Monongahela River sand and gravel? Simply because years of waste from numerous coal tipples along the Monongahela River has about made it impossible to dredge sand and gravel free from coal; an item of impurity next in its injurious effects in mortar and cement mixtures to that of loam. I never hesitate to condemn a flat of sand or gravel the moment a coloring of coal is detected.

The first extensive use of gravel in making concrete in this vicinity was in 1897, since when the increased demand has taxed the capacity of the combined dredging companies. But just as we begin to wonder how long the supply is going to last, a new inven-

tion or new uses of materials are made that solve our most difficult problems.

I am convinced that the many uses of furnace slag are going to meet the enormous demands for clean sand and gravel consumed in the many forms of building carried on in this great center of industry.

Why any architect will allow the filth of ashes, clinker and free coal to enter into fire-proof construction is inconceivable. Not long since I saw an almost dry mix of coke dust, cinder, ashes, plaster, and floor sweepings shoveled into concrete flooring in one of our most important office buildings, a strictly fire-proof building at that.

The question of weight is very important, and the lightness of coke and cinder is the only thing that can be said in their favor. I wish the speaker had dwelt more on this subject in his discussion of granulated slag and slag sand, as I am not so sure but what it can be shown that the substitution of the forms of furnace slags can be made for coke dust and grate cinder, and a concrete be obtained equally as light, strictly fire-proof, perfectly clean and very much stronger for the same cost per square foot of floor space.

I think a little further experimenting will develop a product midway between the ordinary granulated slag and the slag sand that will give the required lightness and strength for building purposes, purer than any sand or gravel or any other materials now in use on concrete construction.

F. Z. SCHELLENBERG—About six years ago we had in this Society a special committee's report on Arthur Kirk's display at the Exposition of foreign road paving blocks. The long report naturally went into the subject of improving the public roads as well as street pavement, and the name Committee on Roads being flippantly given us in recollection of a Quixotic effort by a former committee of that name, induced the writing of a series of educational essays. There was advocated a use for blast furnace slag in improving the foundations of the highways that would take the thousands of tons so expensively being wasted. And perhaps there was also first brought to wider notice here the property iron and cement have of uniting and continuously together resisting strains

in structures, a property due to the increment of expansion or contraction from change of temperature being the same for both. Since then we have also learned that the massive construction of concrete and iron above ground is not only strongest, but is also best in resistance to rust and fire—to slow corrosion or rapid conflagration.

Mr. Shinn tells us that for concrete and mortars slag-sand is the best sand; no matter what the cement be, slag-sand meets the underburned clinker ingredient in the cement in chemical union, and mortar of lime itself it raises in strength hundreds of percentages.

I belive it is certain that our concrete construction now is better conserved where there is continual dampness; it appears that this slag-sand is the right ingredient to silicify the free lime of cement and prevent its efflorescence in dry exposures, an effect for permanence even more valuable than the initial strengthening shown by tests.

As regards Mr. Shinn's sententious review on the uses of the slag in Europe and the newer transformations there and here into even transcendently useful by-product, with the statistics showing the greatest waste in the world to be here at Pittsburg, it behooves us to unite in deprecating a technical folly so brought home to this Society as a subject of some public concern, to invoke opinion for economy which must benefit every inhabitant of the country, high or low, now and in the future.

We may allow unprotested the ephemeral monkey shines indulged in by giddy personages as passing extravagances of weakened individuals, but are we—blind leaders of the blind—to stand in the presence of the crux as the fool that knows not that he knows not, or the simpleton that knows that he knows not, or the dullard that knows not that he knows; or shall we be the wise men that know that they know and prove the ability to teach with effect.

Mr. Shinn, City—The following letter would seem to justify the theory that neither water nor sulphur would produce corrosion of iron, if protected by a sound coating of cement of sufficient thickness to prevent free access of oxygen. In the opinion of mine managers, the sulphuric acid in this water would have caused a

break in this pipe within two years if it had not been protected with a cement coating.

H. C. FRICK COKE COMPANY.

CONNELLSVILLE COKE.

OFFICE OF SUPERINTENDENT OF STANDARD MINES.

MT. PLEASANT, PA., April 8, 1904.

Mr. F. Z. SCHELLENBERG, Pittsburg Pa.

Dear Sir:—Replying to your letter to the 24" cast iron discharge pipe at Standard shaft: This line was put in operation in the spring of 1887. The perpendicular part is 303 ft. deep and the horizontal 130 ft. long. After the lines were in place they were treated with a heavy coating of Portland cement, applied on the perpendicular line with a brush and on the horizontal one with a trowel. Cement had an average thickness where brush was used of $\frac{1}{4}$ inch, and where trowel was used $\frac{1}{2}$ inch.

The first break due to service was in May, 1896, when the foot ell burst. It burst or wore out at the curve of the ell. All the cement had been worn off, due to the action of the water in passing around the curve. This left the cast iron exposed to the action of the acid in the water. It was noted at the time of the break that the metal was $\frac{1}{2}$ inch thick at the edge of the hole, which was about 6"x8". This elbow was replaced and the line next burst on the perpendicular part, about nine feet above the foot ell, on January 11, 1899. It showed that water had gotten to the cast iron and weakened the metal so that a piece dropped out 4 feet long, 2 inches at the top and 8 inches at the bottom and $\frac{1}{2}$ inch thick at the edge. With the above exceptions this line has been in continuous service since 1887, and at present an average of 1,400 gallons per minute, day and night, is pumped through it.

Yours truly,

JAS. S. MACK,

Superintendent.

MR. SHINN—Dr. Michalis brought forward a theory of the hardening of cement (1882) which is recognized as one of the best. He said when Portland cement is mixed with water and hardens thereby there is unconditionally a rearrangement of the molecules aside from and as a consequence of the taking up of water.

About one-third of the whole content of lime crystallizes out as lime hydrate. The crystalline separated lime, being less binding, has rather a tendency to destroy the preparatory cohesion of the cement mass. A portion of this lime hydrate remains permanently in that condition and is evidenced by the deposit under favorable conditions of a cauliflower like efflorescence on the surface of the concrete.

When, however, slag (Pozzuolani) is added to the cement, the soluble silica therein contained furnishes the chemical equivalent necessary to convert the whole of this lime hydrate into a lime hydro-silicate, thereby converting this element of weakness in the Portland cement into an element of strength in the increased volume of cement produced by such addition.

There is no efflorescence from slag Pozzuolani cement is well known to those familiar with that material. Tetmeyer mentions in his report that there is little or no efflorescence when Portland cement is used for mortar with slag granulate as the aggregate.

Mr. A. D. Wilkins—Several concerns in this country, notably the Illinois Steel Company, use slag as an ingredient in true Portland cement, the product being the same as what is called in Germany "Eisen Portland cement," it being understood, of course, that the term Portland cement can be correctly applied to any material having the same chemical composition and made in substantially the same way as ordinary Portland cement, the sources of the ingredients being immaterial.

MECHANICAL SECTION.

[Paper read before the Mechanical Section at its March meeting.]

HIGH PRESSURE HYDRAULIC DISTRIBUTION OF POWER WITH SPECIAL REFERENCE TO ELEVATOR MACHINERY.

BY H. D. JAMES.

GENERAL.

The subject of hydraulic transmission of power is similar in many respects to electric transmission of power. Unlike electric transmission, however, very little, if anything, has been done in this country towards a public distribution of hydraulic power. Only private plants and possibly some small towns are supplying this form of power for elevator service, cranes, presses, sewerage pumps, motors, etc.

The public water supply in towns and cities is generally from 30 to 90 pounds, depending upon its topography. In a number of our large cities there has been installed a system to be used for fire purposes only, which runs 250 to 300 pounds pressure, but as far as I know it has never been used for general power purposes.

CENTRAL STATIONS.

The advantages of generating power in large quantities at a central station are well known to every engineer.

At Kensington Court, London, an isolated station had been installed by an independent company to operate at 450 pounds pressure. When the London Hydraulic Power Company's lines were extended as far as this, it was found cheaper to change these accumulators from the 700-pound pressure mains, losing the other 150-pound pressure, than to operate this isolated station. (Inst. C. E. Vol. 115, Page 226.)

(a) When hydraulic power is developed at such a central station one of the chief advantages is due to the great increase in the efficiency of the pumping machinery. A high duty pump-

ing engine is from two to three times as efficient as the ordinary compound duplex pumps.

(b) Also all noise and vibration due to placing a pumping plant in an office building or hotel is avoided.

(c) The space occupied in the building by the usual pumps and tanks can be used for other purposes. This space is considerable when the building is equipped with the usual low pressure hydraulic elevator installation.

(d) The maximum capacity of the central station will not have to be as great as the sum of the maximum capacities of the private power stations it would replace.

(e) There are no tanks, or pump suction and discharge chambers to keep charged with the proper quantity of air. Accumulators, where it is necessary to use them, are entirely automatic. The only attention they need is that necessary to clean and oil them.

(f) A supply of high pressure water is available at all times for extinguishing fires. This renders unnecessary the keeping up steam at all times to operate fire pumps, or the replacing of a large storage tank of water on the roof of a building for fire purposes.

PRESSURE.

When power is distributed by means of water it is necessary to use a high pressure in order to reduce the quantity of water transmitted. The use of high pressure.

(a) Reduces the size of pipes required for the same per cent. of drop, and thus (with certain limits of pressure) saves in the first cost of the installation.

(b) The mass of water handled is much smaller, thus reducing the time required to accelerate or retard the flow of water, also reducing the shock due to sudden stoppage of the flow.

The limit to the pressure used for distribution is determined by increasing this pressure, until the increased cost of construction offsets the saving in power. The uses to which the prospective customer expects to put this water also influences the choice of pressure.

The topography of the section served will likewise enter into the calculation. A hilly section requires a greater pressure than a level one.

ADVANTAGES OF WATER POWER.

(a) *Engine efficiency.* Pumping water is almost an ideal duty for a steam engine. The power delivered is directly proportional to the revolutions per minute of the engine and the efficiency drops off very little at slow speeds. This renders the all-day efficiency of the engines high, compared with engines used for generating electricity.

(b) *The accumulators* used for storing this energy are reliable, require little attention, have a low rate of depreciation and are mechanically efficient.

(c) *Regulation.* No governors or other speed devices are necessary. The throttle valve to the pump is controlled by the accumulator. As it rises, steam is cut off the pump; and as it descends, steam is admitted to the pump.

(d) *Fire risk.* The presence of large quantities of water and the absence of any inflammable apparatus, except the boilers, reduces materially the liability of fire, either at the power house or the customer's building.

(e) *Transmission.* Water being practically inelastic there is little danger to life by the wrecking of a power line, as would be the case with steam or gas, or any danger of shock as with electricity.

The above advantages have enabled hydraulic power to compete favorably with electric power, in the cities where it has been installed. In a paper read before the Institute of Mechanical Engineers, July, 1895, Mr. Ellington gives a cost in round numbers of 40% more for generating electrical energy over hydraulic during the previous year in London. A portion of this difference was readily accounted for but a large portion of it was undoubtedly due to the superior efficiency of the hydraulic system.

Freezing. If the pipes are properly buried in the ground there should be no damage caused by cold weather.

Flexibility. Unlike electrical power, where both alternate and direct current are used, there is but one kind of hydraulic power, its only variation is in the pressure. When a different

pressure is desired it can readily be obtained by means of a differential system of plungers at from .85 to .90 per cent. efficiency.

Should it be desirable to transmit power at a high pressure and reduce the same in a building to operate a low pressure elevator plant, already installed, a pressure reducer in the form of a hydraulic pump could be used. This could be made duplex and the valves connected similarly to a Worthington pump. By placing the machine vertical and properly balancing, the discharge from the high pressure ram could be delivered direct to the pressure tank and the pump made practically double acting.

Losses. The principal losses are as follows:

(a) Water used by the customer but not registered owing to leaks, the meters being placed in the discharge line; also by the meters not registering accurately small volumes of water.

(b) Water run to waste in order to maintain circulation in exposed sections of the pipe line during severe cold weather.

(c) Boiler losses (also condensation of steam in pumps and pipes) due to keeping up steam during the hours of small demand.

APPLICATION.

(a) *Elevators.* This is by far the most extensive application for such a hydraulic power system. The hydraulic elevator has always been and is today the most suitable type of elevator for tall buildings. This fact is easily verified by visiting the large office buildings and hotels in this city, New York, Philadelphia, Baltimore, Chicago, etc. It is the only type of elevator that has come into general use for high rises and fast speeds. In several places in this city, gas or electricity has been used to pump water for hydraulic elevators. How much better it would be to furnish the customer with a power that can be used directly for his elevators and not first converted into some other form of power.

In a number of smaller buildings hydraulic elevators would be more satisfactory if it were not for the cost and space occupied by the pumping plant, also for the low efficiency of such a pumping plant.

The question of night service in a small building is also troublesome if a pumping plant is installed, for it requires the attendance of a night engineer as well as an elevator operator.

(b) *Cranes.* Hydraulic cranes, of various types, have been in use for many years with very satisfactory results. Such hydraulic cranes could be installed to good advantage to replace many of the hand cranes now in use. For certain purposes hydraulic cranes are preferable to any other type; especially in foundries where there is a good deal of dust.

(c) *Presses.* This is another very useful application of water power. Under this head may be included all hydraulic punches, riveters, hammers, etc.

(d) *Fire Hydrants and Sprinkler Systems.* As previously stated one of the great advantages of hydraulic power is the safety it gives against fire. The high pressure water is connected to a special hydrant that also has a connection to the low pressure service main, and is in the form of an injector. It can be adjusted to give any pressure between these two pressures.

While witnessing a test of one of these injector hydrants at Albert Docks, London, more than twenty years ago, Sir Henry Bessemer said "This great invention makes London safe from fire." (Inst. C. E. Vol. 94, Page 54.)

After the introduction of a high pressure water supply for fire purposes in Manchester, in 1887, the fire loss was reduced 6-7. In Liverpool this fire loss was reduced $\frac{3}{4}$. (Inst. C. E. Vol. 94, P. 54.)

The sprinkler system may be connected to such a hydrant and made automatic in its operation by the use of a small accumulator.

This high pressure system should reduce the general insurance rates in any given district where it is installed.

(e) *Sewerage Pumps.* Hydraulic power has been very successfully used to pump sewerage, the discharge from the motor cylinders helping to flush the sewer. Its most extensive application is at Buenos Ayres, where the sewerage for the whole city is pumped by hydraulic power. Also very reliable pumps of this type can be used to empty "sumpt pits" in buildings.

(f) *Motors.* Hydraulic power can be converted into rotary motion by means of water wheels and used to drive shafting, etc., but it is not as well adapted for this purpose as electrical

power and where the latter can be obtained it will generally be used.

(g) Hydraulic power can be used for opening draw-bridges.

(h) It is also used for working the bellows of organs.

PRESENT STATUS OF HYDRAULIC TRANSMISSION OF POWER. PUMPS.

From the minutes of the Institute of Mechanical Engineers for 1895, page 354, I have taken the following table, compiled by Mr. E. B. Ellington, who has been prominently connected with many of these high pressure installations, and has done much of the designing himself.

Place.	Year of Establishment.	Length of Mains, Miles.	Largest Diameter of Mains, Inches.	Engine Horse-power I. H. P.	Del. of Water per week, Gallons.	Number of Machines Worked.	Pressure per square inch in Pounds.
Hull.	1877	2-½	6	250	100,000 to 500,000	58	700
London	1884	76	7	3400	9,500,000	2300	750
Liverpool	1888	18	6	800	1,000,000	453	800
Melbourne	1889	18	6	800	1,500,000	413	750
Birmingham	1891	3-½	6	52	78,000	.....	700
Sidney	1891	12	6	688	740,000	200	750
Antwerp	1894	4-½	12	1000	3,300,000	Turbines at 3 Sta.	750
Manchester	1894	12	6	800	1,000,000	247	1120
Glasgow	1895	9	7	600	Not Started	.....	1120

From this data it will be seen that the first hydraulic power plant was installed in Hull, in 1877; by 1895 nine cities were equipped with a high pressure hydraulic system aggregating 165 miles of mains, representing 8,390 I.H.P. and delivering over 22,000,000 gallons of water per week, against a pressure ranging from 700 pounds to 1120 pounds per square inch. In 1899 the miles of pipe in London had increased to 106, and at present there are about 140 miles of pipe laid in the streets, embracing Kensington on the north side and Vauxhall Bridge and Surrey Commercial Docks on the south side of the river. Power is supplied by seven pumping stations delivering

a minimum pressure of 700 pounds per square inch; some of the stations working at 750 pounds and others at 800 pounds. 16,000,000 gallons (in round numbers) are being delivered per week, supplying nearly 5,000 machines and presses.

Table No. 2 shows the development of this installation.

	1887	1893	1895	1899	1903
Miles of mains laid	27	67	76	106	140
Number of Pumping Stations	1	3	4	.....	7
I. H. P. provided	800	2600	3400	4600	.....
No. Machines in use	600	1900	2300	3700	5000
Gal. of press water pumped per week	2,000,000	7,540,000	9,500,000	13,000,000	16,000,000 Gals. of press water per week
Capital Expended	£ 150,000	£ 421,000	£ 472,000	.....	.....

Population in 1896 estimated at 6,000,000.

In Liverpool to-day there are over twenty-four miles of street mains constantly charged with water at 750 pounds pressure, supplying over 2,400,000 gallons per week and serving over 900 machines and presses.

Table No. 3 shows the progress this company is making.

Date.	Gals. of press water pumped per week.	No. of Machines in use.
1893	463,000	284
1895	619,000	452
1897	1,442,000	574
1899	1,882,000	689
1901	2,001,000	794
1903	2,430,000	915

Population in 1891—518,000.

PUMPS.

The equipment of the first pumping station in London consisted of four compound pumps of 200 I.H.P. each, 3 cylinders with the H.P. cylinder in the center, 19 inches dia. each L.P. cylinder, 25 inches dia. 24 inch stroke; plungers single acting 5 inches dia.

These pumps delivered 240 gallons per minute at 200 ft. piston speed against 750 pounds pressure and could be safely run up to 250 ft. piston speed.

At a test made March 10th, 1887 (minutes Institution of Civil Engineers 1887, vol. 94), of 8 hours, and 50 minutes dura-

tion, these pumps developed one I.H.P. per hour with 2.19 pounds of coal or 19.79 pounds of steam. Later, during regular working conditions, they consumed 2.93 pounds of coal per I.H.P. per hour. Steam pressure 82½ pounds.

Triple expansion pumps are now used which develop an I.H.P. per hour with 15 pounds of water. At Glasgow, Scotland, there are six triple expansion pumps of 200 I.H.P. each, operated at 150 pounds steam pressure. H.P. cylinder 15 inches diameter; Int. Cylinder 22 inches diameter; L.P. Cylinder 36 inches diameter and 24 inch stroke. Pump single acting plungers 5 inches diameter.

Table No. 4 (compiled from data Institute of Civil Engineers, vol. 115, page 227, etc.) gives the relative efficiency of these pumps.

Station.	Steam Eng.	Single Acting Pump.	Steam Press.	Water Press.	Lbs. Steam per I. H. P.	Reference.
Falcon Wharf, Lon.....	Comp. 19 x 2, 25 in.	5 in. (?)	82-½	750	19.79	Inst. C. E. Vol.94
Melbank, Lon.....	Same (?)	Same (?)	94	750	17.71	Inst. C.E.vol. 115 p227
Wapping, Lon.....	Triple 15 & 22 & 36 x 24	3-5 in. plungers	143	750	14.1	M.E.'94 p536-51
Manchester.....	15 & 22 & 36 x 24	3-5 in. plungers	120	1120	....	.. ..
Glasgow.....	15 & 22 & 36 x 24	3-5 in. plungers	150	1120	.....	.....

All the above engines deliver from 200 to 250 gallons per minute. Piston speed 200 to 250 ft. per minute.

Water is pumped from the storage tanks placed above the level of the engines. This water is filtered and purified; all pumping being done by hydraulic pumps. This method of pumping is more efficient and permits the filtering process to continue during the night as these pumps can be regulated automatically.

Stations of 1,200 I.H.P. seem to give the best results.

These tests were made a number of years ago and now much better efficiencies are guaranteed, pumps are sold to-day to deliver an I.H.P. per hour on a little over 11 pounds of steam. (Engineering Record Nov. 16, 1901.) Also steam engines using super-heated steam, have given even better results. (Trans. Am. Soc. Mech. Eng. Dec. 1903.)

Accumulators are provided at each station, generally in pairs. Their combined capacity in London in 1893 (Inst. Civil

Engineers, vol. 115, page 226) represented less than one-half minutes capacity of all the pumps. Table 5 gives details of some of these accumulators.

Station.	No. of Accumulators.	Diameter.	Stroke.
Falcon Wharf, London	2	20 in.	23 ft. 0 in.
Milbank, London	1	18 in.	20 ft. 0 in.
Philip Lane, London	1	18 in.	20 ft. 0 in.
Wapping, London.	2	20 in.	23 ft. 0 in.
Glasgow, 1st Station	2	18 in.	23 ft. 0 in.
Manchester Station	2	18 in.	23 ft. 0 in.

Pipes. The pipes are of cast iron seldom over 6 inch diameter with flanges set back a little from the ends. The joints are made with two bolts, are male and female, and packed with gutta-purcha rings set in V shaped grooves. The velocity of the water in these pipes seldom exceeds 5 or 6 ft. per second.

A test made on a pipe three miles long at a velocity of 2.83 ft. per second gave a drop of about 23 ft. head per 1,000 yards. (Inst. Civil Eng. vol. 94, page 8.)

Prof. R. H. Smith (Institute Civil Engineers, vol. 94, p. 80 and 81) gives the following formula for figuring the horse power transmitted, diameter of pipe, etc.

H.P. transmission $= .262\ V\ p = \frac{7}{10}4\ Q\ p$

V = Cubic per sec. Q = Gal. per minute

p = lbs. pressure per square inch

Friction loss of H.P. $= \frac{2.6}{10}10\ \psi\ Q^{3} = \frac{L}{d}5$

Q = gallons per hour. d = diameter in inches.

L = length in feet. ψ = coef. of hyd. resistance $= .002 - .008$ say $.007$

$$d = 4.09 \sqrt[5]{\frac{L \times HP^{2}}{B\ p^{3}}} \qquad \left(B = \frac{\text{H.P. lost}}{\text{H.P. trans}}\right)$$

Registration of Supply. The commercial success of a public distribution of hydraulic power depends largely upon the ability to accurately measure the water consumed by each customer.

Unlike electric meters the hydraulic meter measures the quantity of water consumed irrespective of the pressure at

which it is delivered, also the most successful water meters are those that operate at low pressure, as most high pressure meters do not measure accurately small quantities of water; such as are due to leaks of various kinds. At present most of the water from these high pressure mains is measured by low pressure meters placed in the discharge from the machine. This method does not register any water that may be lost by leaks while passing through the machinery, which is sometimes large. Even with these defects to contend with an average of 92 per cent. of the total water pumped is registered in London and 95 per cent. in Liverpool. Lately high pressure meters are made which are more accurate and these are coming more into use.

On October 20th, 1896, Mr. Gustave Kaufmann read a paper before this society, giving an outline of a high pressure hydraulic system designed for Pittsburgh. This subject should be of even more interest to the public now than it was in 1896.

In this country all installations have been operated from private plants. The largest is that now being erected in the Metropolitan Life Insurance Co.'s building in New York City, where nearly fifty (50) elevators will be operated in the near future. The power plant is being designed with a view to extensive additions of elevators later.

The Prudential Insurance Company of Newark, N. Y., has about forty (40) elevators now in operation, scattered through several buildings.

The Land Title Building in Philadelphia has recently been equipped with high pressure elevators.

West of here there are several recent installations: First National Bank, Chicago, seven (7) elevators; Wells Building, Milwaukee, seven (7) elevators; Chamber of Commerce, Minneapolis, five (5) elevators; National Bank of Commerce, St. Louis, four (4) elevators; Singer Mfg. Co., South Bend, Ind., thirteen (13) elevators; Citizens Building, Cleveland, six (6) elevators.

Here in Pittsburgh two large plants are being erected, one for the estate of Henry Phipps, which will start up with eight elevators, two of which will lift 10,000 pounds load; the other

for Henry W. Oliver, which will have eleven elevators at first. Both plants have been designed with a view of operating an increasing number of elevators in the future.

At present the American practice is to make the accumulator capacity equal to 15 per cent. of the total elevator capacity. This applies, however, to private installations, as above enumerated.

ADVANTAGES OF HYDRAULIC POWER FOR ELEVATORS.

First. (a) A hydraulic apparatus is hardly and does not depreciate rapidly. It is not uncommon for a hydraulic elevator to be operated for fifteen to twenty years.

(b) It is not liable to temporary shut-downs during working hours.

Second. Ease and efficiency of control:

(a) The speed of the elevator can be adjusted by the opening of the valve, with little loss in efficiency and can be so run indefinitely.

(b) The lifting capacity and maximum speed can both be increased by increasing the water pressure within the limits of the strength of the machine. Elevators that have been in operation for five or ten years are often "speeded up" in this way by a change in the pump.

(c) The speed can be increased by enlarging the hydraulic connections.

(d) The start and stop is positive, the water acting directly on the piston or plunger.

(e) The machine can be built for any desirable speed as the action is positive and of the same kind as the car, viz: reciprocating.

Third. Safety.

(a) No brake is necessary as water is practically incompressible and forms its own brake.

(b) The machine has positive limits of travel, inherent in its construction, and when properly designed the car cannot over-travel.

(c) The maximum lifting force can never exceed the pressure of water times the area of the piston; which is a con-

stant function. If the car is overloaded the machine simply does not lift it.

In lowering with an overload the speed can be readily kept down to any desired amount by properly operating the valve.

Should the car become obstructed in its passage no increased power is exerted by the machine.

(d) Any defects in joints or stuffing boxes make themselves known at once by the leakage of water.

(e) Hydraulic machines do not require expensive spare parts to be kept in stock, oil and packing being the only articles needed often. With proper design and care good packing should last several months.

(f) Dirt is always detrimental to machinery; but it affects hydraulic elevators less than any other type.

(g) Hydraulic elevators have few parts that are apt to get out of adjustment and need constant attention.

DISADVANTAGES OF HYDRAULIC ELEVATORS.

First. Efficiency.

Hydraulic machines, as generally constructed, consume a constant amount of water per trip independent of the load carried; and, therefore, have a less "all day efficiency" than an electric machine which consumes power in proportion to the load.

However for the same maximum load the hydraulic machine is 100 to 125 per cent. more efficient.

The method of counterbalancing also affects the efficiency. The hydraulic machine is single acting and, therefore, the counterbalance must always be less than the total car weight, where, with a drum and worm gear machine the C.B. equals the car weight plus half the average load. This latter type of machine with an average load in the car is evenly balanced and consumes only enough power to overcome friction. This is the reason that electric machines with their low actual efficiency have a higher all day efficiency when in proper working condition.

AMERICAN TYPE OF HIGH PRESSURE ELEVATORS.

Quite a number of the elevator machines in use abroad have either been built or else designed in this country by American engineers. Many machines of this type have been designed and built under the personal supervision of Mr. Thos. E. Brown, Jr., also Mr. Geo. Reynolds and Mr. Thorpe have contributed much towards our knowledge of high pressure hydraulics.

The High Pressure Hydraulic Elevator Machine used today in this country is the geared type of plunger machines. On the end of the plunger away from the cylinder are mounted two or more sheaves; at the opposite end of the cylinder are also mounted one or more sheaves. The ropes are wound from the plunger sheaves to the cylinder sheaves and back again several times, then to the car. The other end of the ropes is anchored to the cylinder. As the plunger moves out of the cylinder the car is lifted. The cylinder is inverted so the plunger moves down when the car rises; in this way the weight of the plunger and the traveling sheaves partly counterbalance the car weight. The additional counterweight necessary is placed in an extension of the iron strap which carries these traveling sheaves. The machine is suspended from beams in the hatchway and the plunger strikes a cushion buffer placed on a foundation, at the limit of its travel. The cushioning is generally effected by a piece of timber set on end. The cylinder is also tied to the foundation by means of the "T" iron rails which guide the traveling sheaves and counterweights.

The only packing in the machine is in the stuffing box at the end of the cylinder, which is very accessible and any leakage is easily detected. Water is admitted and discharged through the same cylinder port. The supply is generally between 700 pounds and 800 pounds per square inch and the water is discharged at 75 pounds to 90 pounds per square inch; generally to a roof tank from which the pump suction is taken. The discharging against pressure prevents the cylinder from drawing should the operating valve leak.

TESTS.

A test for efficiency was made on one of the elevators in the Prudential Building, Newark, N. J., by Mr. J. R. Furman. The data of the machine is as follows:

7-$\frac{1}{4}$" Plunger
6:1 Gear
4-$\frac{5}{8}$" Ropes
140 ft. Rise
Gross Pressure 750 lbs. per square inch
Back " 80 lbs. to 100 lbs.

All tests made at a car speed of about 5 ft. per minute.

Load in car . . . . . one person
Elevator efficiency 50%

Load in car . . . . . 1500 lbs.
Elevator efficiency 61%

Load in car . . . . . 2500 lbs.
Elevator efficiency 77%

In the above test the actual load was the load in the car, plus the unbalanced weight of the car, although only the load in the car was used to figure the elevator efficiency, as this is the useful load.

The average gross efficiency which is used as a basis for designing this type of machine is about as follows:

2:1	Gear	85% Efficiency
4:1	"	82% "
6:1	"	80% "
8:1	"	75% "
10:1	"	70% "

The total load used in this latter case to include from 500 lbs. to 1,000 lbs. of unbalanced car weight.

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DISCUSSION.

CHAIRMAN—I would think a great saving could be effected by a central hydraulic system to work the elevators in the tall buildings in Pittsburgh, especially as the territory in which the pipes would have to be laid is not great.

MR. FLANIGAN—I believe that until recent years, in this country, the principal experiences of high pressure hydraulic transmission has been in the rolling mills and steel works practice, and there it has been found not only better than anything else but almost the only thing for many purposes. We can hardly imagine some of the appliances worked by hydraulic power as being worked by anything else, and they have proven very sufficient with a comparatively ordinary class of labor to tend to them. The tendency of late years in mill practice, I believe, has been towards higher pressures than were formerly used. Twenty years ago, perhaps, pressures higher than four hundred pounds were not very common in mills and steel works. I think at the present time the tendency would be to run from 750 to 1,000 pounds pressure, and it seems to be noteworthy that the elevators are coming the same way. I believe that many of the elevators used heretofore ran at perhaps 150 lbs.

MR. CRONEMEYER—I would like to ask Mr. James what the length of these cylinders are that operate the elevators. I notice there are about three or four sets of sheaves on the

elevators and to operate a building, say 12 or 14 stories high, would require a pretty long cylinder.

MR. JAMES—The cylinders are in the neighborhood of 40 or 50 feet long. If you have a rise of 200 feet and geared four to one, you have a 50 foot stroke. The only limitation on the stroke on a machine of this type, is to have a plunger of sufficient size to give it stability. Another type of machine where you depend on the water column, under the piston to compensate for the variable head, you are limited to practically 30 ft. unless there is some special device to take care of an additional column of water.

CHAIRMAN—If a company would erect a power plant and build a line to supply power to the different customers, it ought to be a great deal better than to have the room taken up in their own buildings with an inefficient pumping system. The laying of the pipes, of course, is one trouble in having to take up the streets, but they lay the electric conduits, etc., for the telegraph and telephone companies, and the pipes required are not very large. What size are they?

MR. JAMES—Six inches seems to be about the largest. Of course where there is a large quantity of water they use several of these six-inch pipes. There is no objection to laying pipes all in the same trench, but with the electric wire it would be a different proposition. In hydraulic power, unless there is danger of a cave in or something of that kind, one route is as safe as another.

MR. UNDERWOOD—I would like to say that the installation for the Oliver Building is something on this system. The pumping plant is back of the Duquesne Club and the trench is laid under the street for perhaps a hundred yards; so really Pittsburgh has, on a small scale, a system of this kind.

MR. JAMES—There have been some very curious results in various places, in connection with power transmission. In New York they have a steam system, and in Paris they have quite an extensive system of air pipes, from which a number of elevators have been operated by means of an indirect system. In fact right here in our own city, there are two large interests who are providing for their own private high

pressure distribution; and I find that through the West, even for comparatively small buildings, where there are half a dozen or more elevators, they are taking more kindly to this high pressure system than to others, owing to the small space occupied by the pipes. This seems to indicate that there is sufficient advantage in it to make it profitable to even small users. From these results and those obtained abroad, it should prove to us that it is not only good from an engineering standpoint, but that such companies should pay very good dividends, and in fact the foreign companies are paying well on the investment.

MR. BLUM—Doesn't it seem rather dangerous to use high pressure fire supply for hydraulic elevators? One can conceive that just at the very time when the greatest water supply would be needed for fire, the greatest power would be required for hydraulic elevators in the moving of people down from our large buildings. It would seem that while this hydraulic power system would be meritorius, there should be a perfectly independent supply for fire purposes. Engineering News, March 3rd and 24th, 1904, have reports on proposed high pressure fire sinus for Chicago and New York, and in these articles the writer advocates the same independent fire supply.

MR. JAMES—In connection with that, you are lowering heavy loads and not lifting, and as very few people would want to go up in the car, the car would go up light and could be lifted with a very much reduced pressure. Now a hydraulic supply ought to have a considerable capacity and a local fire in its building, such as the Frick Building, should not require enough high pressure water to drain that section of the town. It is quite a different proposition to lift a light car than one with 25 people in it. I know that in Manchester and Glasgow and London, there has never been any difficulty of that kind. They have always had enough water for both purposes. The amount of high pressure water used for hydrant purposes is very small. When you get to the higher floors you need to re-inforce the city supply with high pressure water. I understand in talking to a fire underwriter that they object very much to having a stream under high pressure turned on any

property, as the water does more damage than the fire. In Philadelphia they have installed quite an elaborate system to be used for fire purposes. Probably they have enough fires in that portion of the city to operate the pumps every day or two; but if they had a few elevators it would require some of the pumps to run continuously and insure the plant being always operative.

MR. CRONEMEYER—You say that in raising a light load the quantity of water required, or rather the power required, can be altered, that is by using a smaller pressure. The quantity of water, of course, would remain the same, would it not?

MR. JAMES—There have been two or three "double power systems" put in use but they had to abandon the idea of regulating the power automatically, so they introduced a system of regulating by means of a lever, with the result that the operator always moved the lever so as to get the highest pressure. It has, therefore, been found that the additional pipe costs more than the wasting of the additional power. One objection to hydraulic elevators, is, that they waste power with light loads. In regard to the height of the buildings, a fifty foot additional building means 25 lbs. more pressure on the water system. They could readily take care of the difference in rise of any of the buildings.

MR. FLANIGAN—In the case of large landowners or any large corporation controlling considerable territory, in the business portion of cities—it seems to be their adopted policy of late to put in a central power plant. If they intend to put up several buildings they do not put up one building with a power plant in the basement, and put up another one also with a separate power plant in the basement; they adopt the central power plant. There are a good many things that hydraulic power is useful for. It has been found available in large operations, such as immense presses. It may be that if we had a system installed in the cities of this country they would develop a number of small drains on it in the same way. Small manufactures might find it to their interest to put in appliances to be operated by hydraulic power where they use other forms of machinery now. It is not so long since the forging press

has displaced the steam hammer in forges. We might come to it yet that in the small forge shops they would displace small steam hammers. In various other ways, if water power were available, we might be able to make use of it. Take an important appliance in a rolling mill, the ingot stripper; it would be hard to imagine the same efficiency being obtained in any other way. With the differential cylinder of to-day, we have the entire area, for the instant to start a mould off an ingot, and at the very instant that the separation takes place and the mould begins to raise, the machine practically cares for itself, and the only water used in raising is the difference between the two areas, barely enough to lift the mould; so that there is a hydraulic machine which wastes very little water. I think in the Steel Car Company's plant they have several miles of water mains, all told, running up to 1,000 lbs. pressure, and in their great presses that pressure is increased by hydraulic intensifiers to from 1,500 to 2,500 pounds; and there is a case where they do not waste much power either. They have water at 1,000 lbs. and they can perform part of their work with that and if they come to a sticker, they can bring the pressure up to 2,500, so that the bulk of the work is done at a calculated pressure, and it is only when the intensifier is needed that it is used. It is immediately available merely by pulling the lever, so there are no losses from, or trouble about it.

Mr. Boltzell—About stripping ingots, that work is being done successfully in a number of mills to-day, by electric power. I think in the last four or five years there have been about 10 electric strippers put in to one hydraulic. I think there is a great deal to be said in favor of electric strippers as compared with hydraulic.

Mr. Flanigan—I had the pleasure of helping to build an electro-hydraulic stripper in the days before the electric stripper, Mr. Boltzell speaks of, was introduced. The stripper was on a traveling bridge, so as to command the yard and take the stripper to the ingots in place of the reverse. The first thing they called for was to have a double stripper, these two cylinders to remove two moulds at a time, the way we fre-

quently build the hydraulic ones. By the time we got the two cylinders on the trolley, and the little tank to carry sufficient water for them, and the pumps to pump the water, and the electric motors to run the pumps, we found that we had a pretty big thing. The design was made, fully completed, and sent to the parties asking for the proposition and it met with their approval in every way except one, that you were moving such an enormous tonnage. You moved some hundred of tons of machine to strip a few tons of mould from the ingot. However, they simply cut the thing in two and contented themselves with the one stripper, and it was built that way. I believe a second one was installed, but, as Mr. Boltzell has remarked, they have made the electric stripper successful, and where they want it to command a yard and want it on a traveling bridge, they build the electric one in preference to the hydraulic, because you can do it with not much more weight than an ordinary electric traveling crane, whereas the electro-hydraulic one is a very heavy machine.

Mr. Stucki—It just runs in my mind that the Railroad Company with which I used to be conected, had exceedingly good results from hydraulic cranes in their wheel foundries. They were specially designed for this purpose, by Wm. Sellers & Co., and have been in constant use for over twenty years. Their motion is very steady and smooth, which makes them very adapted for moulding wheels, and similar work.

We used hydraulic presses quite extensively, as all the flanges boiler sheets, dome castings, cylinder head castings, etc., were pressed into shape thereby. The water pressure was 1,450 lbs. per square inch. This same pressure was used to run the hydraulic engines for the bending and straightening rolls, and hydraulic motors were used to obtain the lift and the carriage travel of the large 17 foot boiler riveter. Both of these motions were easily controlled by two additional levers alongside the riveter.

A steel car plant, with one of which I am at present connected, could not be without hydraulic pressure. We drive most all the rivets in this way, all we possibly can. This is true

economy and makes the best job. I remember I had a paper weight before me for years, which consisted of three boiler plates riveted together by one hand, one steam and one hydraulic driven rivet. This joint was split in two, so as to expose the conditions of the driven rivets and their fit relatively to the hole. The hand driven rivet was tight immediately under the head, while the center of the rivet did not fill the hole at all. The steam driven rivet was much better while the hydraulic rivet, although the holes did not match fair, showed a perfect fit all the way through, so much so, that it was difficult to see the parting lines.

In the manufacture of steel cars we naturally use also hydraulic presses, but of moderate capacities; 850 to about 1,200 pounds is sufficient for our purposes. But I understand, that Bethlehem has a forging press of 2,000 tons, which would make about 4,000,000 pounds.

Hydraulic forging presses, upsetting machines and other special hydraulic tools are now indispensable in an up-to-date forging plant. It is usually wonderful, how cheaply the most intricate shapes now can be made. In former years we used straight lines all the way through, thinking that forging could not be made in any other way, but I can show you forms made which are really elegant and which place the material just where it is wanted. May I ask Mr. James, what stresses are usually allowed in cast iron pipes of such a power transmission?

Mr. James—I think one of the principal reasons for using cast iron pipe is its ability to resist corrosion.

The pipes were six inches in diameter, but I do not think the iron had over 20,000 lbs. tensile strength. They were made exceptionally heavy to allow for corrosion and filling on the inside, without interfering with the service.

These plants are put in to run for thirty or forty years and they did not want to have any trouble from sources of this kind.

They made quite a number of experiments with these pipes to ascertain what design gave the best results and found, that when the flange was set back from the end of the pipe

and there were only two bolts, gave it a chance to bend a little. They set a rubber in a V shape inside, so it could come and go just a little and still not have a leak; in some instances these pipes would sag considerably before they gave trouble. Occasionally in winter, the pipe line would open up due to freezing, but came together again when thawed out and did not give any trouble. In this country I do not know of a single pipe line being run in that way with just two bolts.

MR. FLANAGAN—Will Mr. James tell us how they charge the air chamber in a high pressure elevator system?

MR. JAMES—The pump is connected to a small auxiliary tank. Then the auxiliary tank is connected with the low pressure system, and air is pumped in until alll the water is driven out; then they shut it up tight and pump air in the tank, up to 150 lbs. or whatever the air pump is good for; then the pump is cut off and the tank conected with the air chamber by means of a single pipe.

The water from the air chamber goes over to this auxiliary leak and drives the air out of it into the large air chamber.

MR. FLANAGAN—Can you tell us something about water meters?

MR. JAMES—The principal difficulty with the high pressure meters is that when only a small quantity of water goes through it does not register.

The low pressure meters simply discharge into a small tank and this tank is discharged automatically. There is one point I would like to bring out and that is the use of hydraulic pumps in Buenos Ayres, South America. The city level is eight or ten feet below the sea and it is rather difficult to get rid of the sewerage. They have built a number of sumpt pits in the city and empty them with hydraulic pumps.

Those hydraulic pumps work week in and week out without any attention and but little oiling. They are started and stopped automatically. In these power stations, previously described, they do not use steam pumps at all. All the water is pumped with hydraulic actuated pumps, of the plunger type.

MR. FITTS—What would be an average economy of pumps, usually used in hydraulic practice, in buildings here in the city?

MR. JAMES—Any straight line motion pump, that is an ordinary compound, simple duplex pump, is very expensive to operate, because you have got to admit steam throughout the entire stroke. A simple pump runs something like eighty pounds of steam per horse power an hour; a compound pump will cut that down to about sixty. I know of some tests in New York City where triple expansion pumps gave very good satisfaction, they cut the steam consumption down to thirty-five pounds, per H.P. an hour. This refers to water, and horse power, and not to the indicated horse power. Small power pumps will cut the water consumption down to about twenty-five pounds, per indicated horse power per hour. It is only with large pumps they get the efficiency spoken of in my paper.

There have been a number of steam engine tests recently which indicate that there is not an appreciable falling off in efficiency at light loads, but I have not been able to find any tests of pumps, I should judge though that what would hold good on steam engines would likewise apply to pumping engines.

MR. LANE—I ran across a case a few years ago which shows in a crude way the economies gained by the use of hydraulic riveting machines in place of steam riveters. An installation in a boiler shop consisted of three vertical boilers, a corliss engine and two steam riveters. A large flanging press was put in the shop, with the Worthington Compound Duplex Pump, to supply the water, and the steam cylinders were removed from the riveters and hydraulic cylinders put on. The result was a sufficient saving in steam to allow one of the three boiler to be shut down, whereas, three boilers had had difficulty to furnish sufficient steam.

CHAIRMAN—Has Mr. James any account of the proportion of air chambers, or spring fingers, that are used in the lines he spoke of?

MR. JAMES—The spring plunger for relieving the pipes of

shock, seems to be somewhat of an American conception. I did not find any record of them being used in England. It seems the demand on the line is fairly uniform, and I do not believe it has been necessary to use these refinements. In this country we use those small spring chambers, that I showed on the dead ends of the line or where the line terminates abruptly. It prevents hammering, due to sudden stoppage of water. I might add, also, in connection with pipe work that all the valves and fittings, used for the elevator installation in the Metropolitan Life Insurance Building, in New York City, are of cast steel.

CHAIRMAN—We will now discuss the question of strength of flat plates.

MR. JAMES—In reference to the flat plates, I would state that in my thesis at the University of Pennsylvania, I had this subject assigned to me, and I found that, with a very moderate pressure, round plates, supported at the edge, were dished and retained that dish, but I could not split a single plate, nor did they even show signs of failing; with any pressure the apparatus could apply. Of course, with the thicker plates, no results were obtained.

CHAIRMAN---Yes, because a thick plate will tend to break, whereas a thin plate will merely stretch and distortion takes place.

MR. FLANAGAN—I think the interesting feature of the flat plates is for somebody to tell us, about cast iron, where it has been used, and give us a reliable formula for the strength of it. There are cases where, if its strength, admitted the use of it, it would be convenient and we would like the limit of safety, and that is the important matter. Some of the engineers say the best way is not to use it at all, but this is merely evading the question..

CHAIRMAN—I have made a note of the formula I use. It is a sort of home-made affair, but it gives results that I think are safe.

For circular plate supported at edge $t = d\sqrt{\frac{p}{10\,S}}$ and for

Square plate " " " $t = a\sqrt{\frac{p}{S\,S}}$

For S=I usually take 3,000 pounds per square inch for cast iron

t=thickness of plate in inches

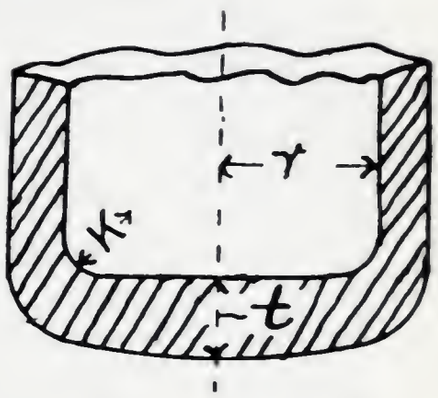
d=diameter of supporting edge in inches

a=side of square of supporting edge in inches

p=pressure per sq. inch uniformly distributed

"Strength of cylinder bottom" formula by C. Bach.

$$S > = p \left\{ u \frac{k}{t} + c \left(\frac{r - 0{,}5\, k\left(1 + \frac{k}{r}\right)}{t} \right)^2 \right\}$$



For Cast Iron u = .8
" " " c = .8
" Steel Casting u = .6
" " " c = .4

Sand p same notation as for flax plates.

MR. BOLTZELL—Oct. 10th and 31st, 1901, there were published in the "American Machinist," several papers on flat plates, by Albert J. Guy, and they were treated mathematically.

MR. STUCKI—In figuring flat boiler plates held by stay bolts, which were an inch apart in both directions, p being the pressure in pounds per sq. inch, uniformly distributed all over the plate and h being the thickness of the plate in inches, I always figured the stress s by the following formula:

$$s = \frac{2\, a^2\, p}{9\, h^2}$$

This is in accordance with well known Handbooks, gotten up by the German Engineers' Society Hutter, and the results have always been very satisfactory.

CHAIRMAN—We have another question for discussion: Location of Neutral Axles on Columns and Beams, Subject to Combined Stresses.

MR. STUCKI—The point is: Where shall we put the neutral axis so as to get the same stress, in the compression, as well as in the tension member of the beam, which is subjected to a vertical load and an end force f. This latter force being an excentric load in pounds, and the cross sectional area of the beam being A square inches, the two distances from the ex-

TO FIND THE WORKING PRESSURE IN LBS. PER SQ. IN FOR A FLAT PLATE OF GIVEN THICKNESS.

R = RADIUS.
P = SAFE PRESSURE IN LBS. PER SQ. IN.
T = THICKNESS. FACTOR OF SAFETY = 8
S = TENSILE STRENGTH. f = COEFF. DERIVED FROM $\frac{1}{8}$ S IN EQUAS. IN LAST COL.

FORM OF PLATE — DIMENSIONS IN INCHES	CAST IRON S=20000	WROT. IRON S=48000	BEST STEEL S=80000	ALUMINUM BRONZE AL. 10% CU. 90% S=90000	CAST BRASS & " COPPER CU.-66% ZN.33% S=25000	GENERAL APPLICATION	EQUATION
CIRCULAR PLATE RADIUS R, SUPPORTED AT EDGES.	$P=3000\frac{T^2}{R^2}$	$P=7200\frac{T^2}{R^2}$	$P=12000\frac{T^2}{R^2}$	$P=13500\frac{T^2}{R^2}$	$P=3750\frac{T^2}{R^2}$	$P=Sf\frac{T^2}{R^2}$ (f=.15)	$P=\frac{6}{5}S\frac{T^2}{R^2}$
CIRCULAR PLATE RADIUS R, SECURED AT EDGES	$P=3750\frac{T^2}{R^2}$	$P=9000\frac{T^2}{R^2}$	$P=15000\frac{T^2}{R^2}$	$P=16875\frac{T^2}{R^2}$	$P=4687\frac{T^2}{R^2}$	$P=Sf\frac{T^2}{R^2}$ (f=.1875)	$P=\frac{3}{2}S\frac{T^2}{R^2}$
PLATE STRENGTHENED BY STAYS a= INS. FROM C. to C.	$P=11250\frac{T^2}{a^2}$	$P=27000\frac{T^2}{a^2}$	$P=45000\frac{T^2}{a^2}$	$P=50625\frac{T^2}{a^2}$	$P=14062\frac{T^2}{a^2}$	$P=sf\frac{T^2}{a^2}$ (f=.3625)	$P=\frac{9}{2}S\frac{T^2}{R^2}$
RECT. PLATE SIDES a & b (a&b) SEC'D AT EDGES.	$P=5000\frac{T^2(a^4+b^4)}{a^4\times b^2}$	$P=12000\frac{T^2(a^4+b^4)}{a^4\times b^2}$	$P=20000\frac{T^2(a^4+b^4)}{a^4\times b^2}$	$P=22500\frac{T^2(a^4+b^4)}{a^4\times b^2}$	$P=6250\frac{T^2(a^4+b^4)}{a^4\times b^2}$	$P=Sf\frac{T^2(a^4+b^4)}{a^4\times b^2}$ (f=.25)	$P=2S\frac{T^2(a^4+b^4)}{a^4\times b^2}$
SQUARE PL. SIDE a SECURED AT EDGES	$P=10000\frac{T^2}{a^2}$	$P=24000\frac{T^2}{a^2}$	$P=40000\frac{T^2}{a^2}$	$P=45000\frac{T^2}{a^2}$	$P=12500\frac{T^2}{a^2}$	$P=sf\frac{T^2}{a^2}$ (f=.50)	$P=4S\frac{T^2}{a^2}$

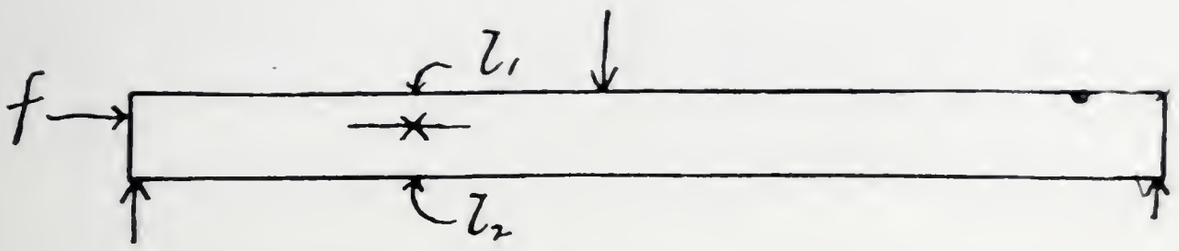
TO FIND THE NECESSARY THICKNESS FOR A FLAT PLATE EXPOSED TO A GIVEN PRESSURE IN LBS. PER SQ. IN. FACTOR OF SAFETY = 8

R = RADIUS. f = COEF. DERIVED FROM $\frac{1}{8}$S IN EQUA'S. IN LAST COL.
P = SAFE PRESSURE IN LBS. PER SQ. IN.
T = THICKNESS. S = TENSILE STRENGTH.

FORM OF PLATE — DIMENSIONS IN INCHES	CAST IRON S=20000	WROT. IRON S=48000	BEST STEEL S=80000	ALUMINUM BRONZE AL. 10% CU. 90% S=90000	CAST BRASS " CU. CU. 66% ZN. 33% S=25000	GENERAL APPLICATION	EQUATION
CIRCULAR PLATE RADIUS R. SUPPORTED AT EDGES	$T=.018257\times R\sqrt{P}$	$T=.011785\times R\sqrt{P}$	$T=.0091287\times R\sqrt{P}$	$T=.0086066\times R\sqrt{P}$	$T=.01633\times R\sqrt{P}$	$T=\frac{1}{\sqrt{15f}}R\sqrt{P}$ (f=.15)	$T=\sqrt{\frac{1}{65}}R\sqrt{P}$
CIRCULAR PLATE RADIUS R. SECURED AT EDGES	$T=.01633\times R\sqrt{P}$	$T=.010541\times R\sqrt{P}$	$T=.0081648\times R\sqrt{P}$	$T=.0076972\times R\sqrt{P}$	$T=.014606\times R\sqrt{P}$	$T=\frac{1}{\sqrt{5f}}R\sqrt{P}$ (f=.1875)	$T=\sqrt{\frac{2}{35}}R\sqrt{P}$
PLATE STRENGTHENED BY STAYS a= INS. FROM C. to C.	$T=.009428\times a\sqrt{P}$	$T=.0060858\times a\sqrt{P}$	$T=.0047141\times a\sqrt{P}$	$T=.0044444\times a\sqrt{P}$	$T=.008463\times a\sqrt{P}$	$T=\frac{1}{\sqrt{5f}}R\sqrt{P}$ (f=.5625)	$T=\frac{\sqrt{2}}{3\sqrt{5}}R\sqrt{P}$
RECT. PLATE SIDE a & b a&b SEC'D. AT EDGES.	$T=.014142\times a^2\times b\times\frac{\sqrt{P}}{a^4+b^4}$	$T=.0091287\times a^2b\frac{\sqrt{P}}{a^4+b^4}$	$T=.0070711\times a^2b\frac{\sqrt{P}}{a^4+b^4}$	$T=.006666\times a^2b\frac{\sqrt{P}}{a^4+b^4}$	$T=.012649\times a^2b\frac{\sqrt{P}}{a^4+b^4}$	$T=\frac{1}{\sqrt{5f}}a^2b\frac{\sqrt{P}}{a^4+b^4}$ (f=.25)	$T=\frac{1}{\sqrt{25}}a^2b\frac{\sqrt{P}}{a^4+b^4}$
SQUARE PL. SIDE a. SEC'D. AT EDGES.	$T=.01\times a\times\sqrt{P}$	$T=.006455\times a\sqrt{P}$	$T=.005\times a\sqrt{P}$	$T=.004714\times a\sqrt{P}$	$T=.0089442\times a\sqrt{P}$	$T=\frac{1}{\sqrt{5f}}a\sqrt{P}$ (f=.50)	$T=\frac{1}{2\sqrt{5}}a\sqrt{P}$

treme fibre to the neutral axis e, and e_2, are as follows, reference being had to the sketch below:

$$l_1 : l_2 = (s - \tfrac{f}{a}) : (s + \tfrac{f}{a})$$



S is the maximum stress to be allowed in the metal. This formula holds good as long as the proportion between depth and length is not excessive. I had more reference to car sills, than anything else. I also took it for granted, that we deal with a steel beam, and this is the reason why the tensile and compression stresses are more alike. If, for instance, cast iron were to be considered, the relative allowable stresses for tension and compression are different and the formula would have to be altered to that effect.

PROF. KINGSBURY—The question really involves not the determination of the position of the neutral axis, on a given section, and with a given load—that is a comparative easy matter; the problem is rather the inverse position; to make the section such that under the loading, the applied stresses of tension and compression respectively, on the outer fibres, will be equal, so that as far as that goes, it will be neutralized most economically. I want to ask Mr. Stucki if this question which he has written, represents a formula for the location of that axis?

MR. STUCKI—I may repeat that this holds good when the columns are not exceedingly long, but when you come to a large proportion between the depths and length it would not be theoretically, any longer, although close enough for all practical purposes. The formula is so exceedingly simple, that I went over the whole matter several times, before I was convinced of its correctness.

MR. FITTS---Does not the neutral axis sometimes come outside the member?

PROF. KINGSBURY—It does sometimes come outside. The determination is very important in the case of the arch, where it is necessary that there should be only compression at all points of the suction, that the joints will not open.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and forty-fourth regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, April 19th, 1904, at 8:20 o'clock.

President J. M. Camp in the chair and 66 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership and present same to the Society for action:

NAME, OCCUPATION AND ADDRESS.	ENDORSED BY.
EDWIN BAILLIE, Resident Manager, Buckeye Engine Co.; h., 239 Atlantic Ave., Pittsburg, Pa.	N. C. Wilson, John W. Landis, W. D. Corcoran.
ROBINSON P. BAINBRIDGE, Superintendent, Blast Furnaces, Carnegie Steel Co., Mingo Junction, O.	J. A. Mohr, Otto Eisenschmil, H. E. Walters,
MURRAY CHAS. BEEBE, Consulting Engineer and Contracting Business, Beebe & Bennett, 2210 Farmers Bank Bldg., Pittsburg, Pa.	Chas. F. Scott, Jno. S. Peck, N. W. Storer.
EDWARD BENNETT, Elec. Eng. and Contracting, Beebe & Bennett, 2210 Farmers Bank Bldg., Pittsburg, Pa.	Chas. F. Scott, Jno. S. Peck, N. W. Storer.
OWILLE BENSON, Engineer, American Bridge Co., Ambridge, Pa.	H. Ely Myers, Richard Khuen, James K. Lyons.
HERMAN F. BUSCH, Asst. Superintendent, Armstrong Cork Co., Pittsburg, Pa.	A. D. Blythe, N. C. Wilson, John W. Landis.

NAME, OCCUPATION AND ADDRESS.	ENDORSED BY.
HEYWOOD COCHRAN, Secy. and Treasurer, Pure Water Eng. and Contracting Co., Johnstown, Pa.	J. E. Whittlesey, J. F. Kuntz, W. O. Abbott.
JAMES W. CRUIKSHANK, Con. Mech. Engineer, Farmers Bank Building, Pittsburg, Pa.	Samuel Diescher, Samuel E. Diescher, Willis Whited.
L. C. DANIELS, Engineer, with Edw. W. Rieck Co., Forbes & Stevenson Sts., Pittsburg, Pa.	Samuel Diescher, Samuel E. Diescher, C. H. Sample.
CHARLES L. HEISLER, Con. Engineer & Pres. of the Heisler Pumping Engine Co., 714 Westinghouse Bldg., Pittsburg, Pa.	W. E. Snyder, Will. H. Baltzell, Willis Whited.
K. B. HUNGERFORD, Mechanical Engineer, The Wagner-Palmos Mfg. Co., Adams St., Fairmount, W.Va.; h., 711 Benoni Ave., Fairmount, W. Va.	D. L. Mekeel, J. L. Klindworth, M. W. Hall.
JOHN L. KNOWLES, Chief Engineer, of Phipps Power Plant, Cecil Ay. & Duquesne Way, Pittsburg, Pa.; h., 1316 Fayette St., Allegheny, Pa.	M. B. Miller, G. E. Flanagan, Willis Whited.
J. RICHARD KOMMER, Superintendent, of the Bradley Mfg. Co., Allegheny, Pa.; h., 74 McClintock Ave., Allegheny, Pa.	Otto Rothenstein, H. C. Cronemeyer, Samuel Diescher.
JAMES T. LIBBEY, Draftsman, with B. & O. R. R.; h., 2003 Braddock Ave., Swissvale, Pa.	Dan. Carhart, R. T. Stewart, Willis Whited.
ALEXANDER H. NELSON, Member of the Firm, Nelson & Buchanan Co., Designing Eng. & Contractors, 200 Lewis Building, Pittsburg, Pa.	Emil Swensson, Chas. Davis, A. G. Shaw.
JAMES A. STEWART, Engineer, Pittsburg Office, McClintock-Marshall Construction Co.; h., 464 Swissvale Ave., Wilkinsburg, Pa.	A. R. Raymer, H. H. McClintic, Willis Whited.
KARL HOFFMAN BUTLER, Draftsman, for H. C. Evert & Co., Patent Attorneys, 305 Smithfield St., Pittsburg, Pa.	E. T. Parker, Frank Irwin, Thos. A. Colliso.

Moved and seconded that the Secretary be instructed to cast a ballot electing these gentlemen to membership. Carried.

PRESIDENT—The next thing for your attention is the proposed change in the by-laws that you heard submitted at the last meeting.

Are you ready for the question? Question submitted and votes were 33 ayes and 23 nays, and the ayes being less than two-thirds of the number present, the motion was lost.

PRESIDENT—We will now have the pleasure of listening to Mr. Hazen on the effects of the Baltimore fire.

THE EFFECTS OF THE BALTIMORE FIRE.

BY MR. W. N. HAZEN.

The ruins resulting from the great Baltimore fire of Feb. 7th and 8th present a vast field of study, and the conclusions to be drawn from such a study tend to confirm our present idea of fire protection. The seven fire proofed buildings, surrounded by ruins, and appearing from a little distance to be uninjured, stand as monuments to the ingenuity of man.

The fire started at 10:48 A. M. Sunday. Feb. 7, and burned fiercely for about thirty hours. About 2,500 buildings were destroyed, spread over an area of about 150 acres or 70 blocks. Baltimore and Pratt streets are the principal thoroughfares east and west, and are very narrow for the service required of them.

The large majority of the buildings were of brick and wood, of slow burning construction, and were used for warehouses, wholesale houses, stores and office buildings.

The fire started in the basement of the Hurst building, corner of Liberty and German streets and Hopkins Place. In a few minutes the building was a sheet of flames, so dense that eye witnesses could not even see the walls. An explosion of gunpowder, stored in an iron box on the pavement on Hopkins Place, so injured the buildings in the vicinity as to make them an easy prey to the advancing flames. Falling walls brought with them electric wires, one of which striking Fire Chief Horton rendered him senseless for several hours, thus depriving the department of his valuable services. By 11:30 the fire was eating its way along the main artery of the city, Baltimore street. I wish I might give you an idea of the fierceness of the fire at that time. The flames were 100 feet wide and blown nearly horizontal for 400 feet or half a block. The wind blew a gale from the south-west, driving the flames first to practically Charles

and Fayette streets, then to the water, taking everything in its course except a few low buildings.



FIG. I. UNION TRUST BUILDING.

The Union Trust Bldg., Fig. 1, was the first of the modern fire-proof buildings attacked by the flames. At this time the building on the opposite corner caught fire, and the authorities decided to dynamite it. After some delay it was done. The concussion broke the windows of the Union Trust building, leaving it at the mercy of the flames. The Union Trust is shaped like the letter L above the first floor, with a stair well in the center of

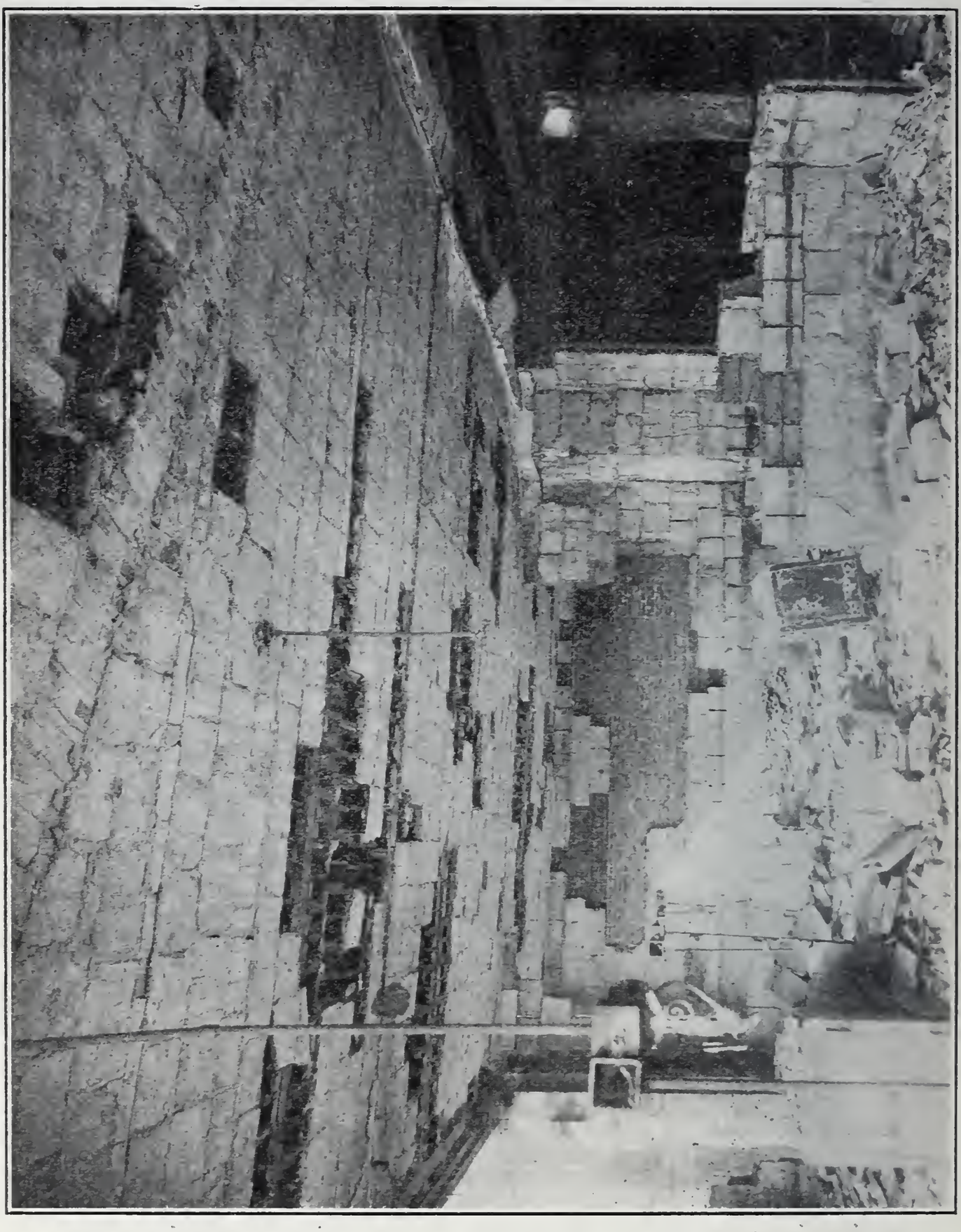


FIG. 2. UNION TRUST BUILDING. THIRD FLOOR.

the west end. The open hall extends around this on three sides, with the elevators on the north wall. The stringers, risers and railings of the stairs were of cast iron. The treads were slate not backed up. After the fire all but the top flight was piled in a heap in the basement. One of the first story columns was exposed after the fire and shows that only $\frac{5}{8}''$ of terra cotta was used on this side. Many similar instances were noted in other buildings in like condition. The halls received light from sash inserted in the terra cotta partitions between halls and rooms, thus depriving these partitions of the quality to resist the spread of the flames. The terra cotta floor arches were intact, but in many places the bottom web or flange fell with the plastering as shown in Fig. 2. Where arches were parallel with supporting beams, the bottom flanges of beams were protected with terra cotta held in place by metal clips. In many such cases the clips gave way, leaving the beam flanges exposed. Except in such cases the terra cotta has not given way more under the beam flanges than elsewhere. The only parts of the steel frame affected are the lintels and facia beams over wide windows on rear of building. These beams were not protected, and being badly warped will have to be replaced. There was a small bar room in the basement, which escaped the fire. The foundation walls formed two sides and terra cotta partitions the other two sides of the room; two doorways being the only openings. In the sub-basement is the power plant furnishing heat, electricity and power for the elevators, all of which is unharmed. The insurance was adjusted on the basis that all above foundations except steel work will have to be replaced.

The Equitable Building, located on the corner of Fayette and Calvert streets, having a frontage of 200 and 100 feet respectively, was built in 1891. The frame work consisted of cast iron columns, and steel beams from $6\frac{1}{2}$ to 8 feet centers. Thin terra cotta floor arches of a circular type, having about four inches rise, were sprung from beam to beam. A rough flooring of 2″ plank was laid directly on the top flanges of beams, and resting on the top of terra cotta arch at center, with space between the tile arch and flooring left open. When the flooring gave way, safes and similar masses dropped a few inches be-

fore striking the arches. It is needless to say that nearly all safes were found in the basement. The partitions were of lime of teal, or a species of plaster of Paris blocks, which disintegrated, thus proving its worthlessness as a protection against fire.



FIG. 3. MARYLAND TRUST BUILDING.

The Maryland Trust Co. Bldg., Fig. 3, located on the corner of German and Calvert streets, is a ten-story and attic building. The walls are at least faced with granite for the first three stories, and above this the brickwork is relieved by highly ornamental terra cotta mouldings. The granite spalled badly, and the terra cotta

mouldings above are much injured in appearance. The west side wall was provided with tinned shutters over all windows. Fig. 4 shows their condition after the fire. Whether they fail-



FIG. 4. MARYLAND TRUST BUILDING. PORTION OF REAR WALL.

ed from heat from without or from within, or both, is a question. Like all other tinned shutters which were subjected to the flames they are now warped and empty shells.

The B. & O. building was of the older type of construction, having heavy load bearing walls. Figs. 5, 6 and 7, show the condition of the exterior.

The United States Fidelity & Guaranty Co., Fig. 8, occupied an old building on the corner of German and South streets. Reinforced concrete floors were placed in the portion of the building shown standing, by the Baltimore Ferro-Concrete Co. The brick walls were very weak, and to support the floors reinforced concrete columns were placed against the walls. The stone used was a broken granite from local quarries. Certain portions of the top floor between girders sound dead when struck with a hammer,

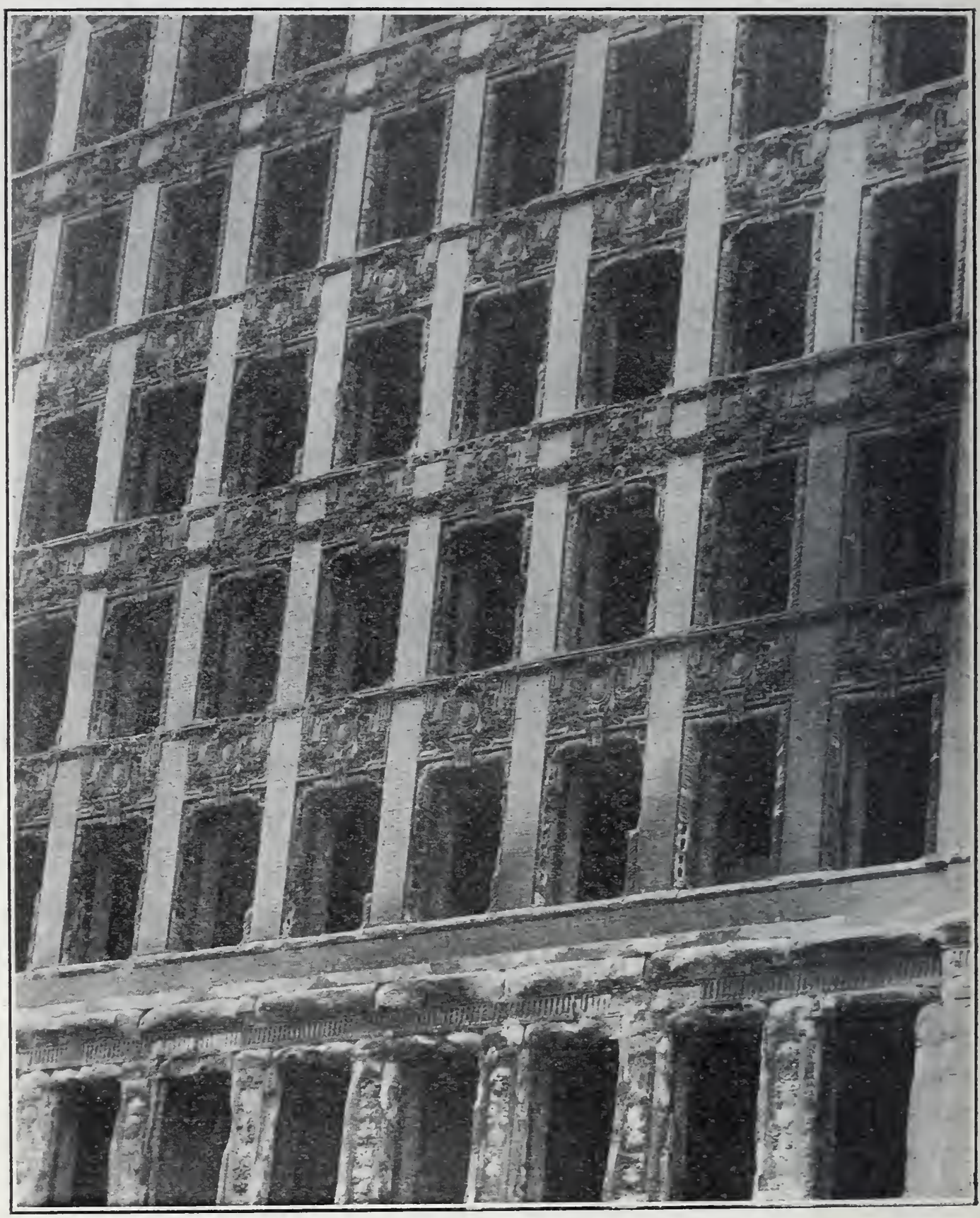


FIG. 5. BALTIMORE & OHIO BUILDING.



FIG. 6. BALTIMORE & OHIO BUILDING.



FIG. 7. BALTIMORE & OHIO BUILDING.



FIG. 8. U. S. FIDELITY & GUARANTY CO.'S BUILDING.

but all below this floor is solid and uninjured. In reference to these floors I have taken the following from the Manufacturers' Record of March 17, '04. "Until last week no load test had been applied to the floors of the annex building, although their substantial condition was evidenced by the failure of the wreckers to bring any force to bear on it sufficient to move the columns or floors. Last Thursday, the load test was made under the supervision of Captain John Stephen Sewell, of the United States Engineering Corps, a recognized expert on reinforced concrete. At the test there were present City Engineer Fendall, Messrs. Strauss and Graham, Baltimore & Ohio engineers; Douglas H. Thomas, architect; John Waters, builder; Mr. Adams, engineer, and others.

"The floor test was made on the second floor, where 300 pounds per square foot was placed on one span, in the form of pile of bricks there feet high and covering a space 20 x 11 feet. The floors were designed for a superimposed load of 150 pounds per

square foot. Under the test made the deflection of the beam was one-sixteenth of an inch. Additional load was then applied, making the total about 400 pounds to the square foot, with practically no change in results.

Alex. Brown & Sons' building was not seriously injured by the fire, on account of its being a low structure. The skylignt was the principal source of danger.



FIG. 9. SAFE DEPOSIT & TRUST BUILDING.

The Safe Deposit & Trust Co.'s building, Fig. 9, was hardly injured. The stone work on the face is of Cheat River Sandstone, which shows the effects of the fire only at the corner next the Sun office. The brick along the north side is spalled and the copper gutter at cornice is being repaired; all showing that the heat on that side must have been intense. The only thing that saved the interior was the interior shutters. On the front the interior shutters stopped at the springing line of the arches over the windows, and above this sparks entered, setting fire to a desk; but otherwise the fire did no damage to the interior.

The electric sub-station had no wood about it and nothing but electric machines in it. The front windows are of wire glass in iron frames, and were uninjured by the fire. Although the fire went all around this building I do not think it a fair test of wire glass. In the first place, it was on the side of the building protected from the wind; and, furthermore, the heat could not have been very intense, as the granite looked as though it had just been finished and the brick work was not discolored. The only real test of wire glass that I know of was in the Merchants' Bank building, located on the south-east corner of Water and South streets. Two small windows, about 16″ x 27″ each, are located on the south side of the building about 16′ from the west corner, and just above the roof of an adjoining low bank building. The heat was so intense as to spall the granite sill under one window to a depth of about $\frac{3}{4}$″. Although the glass is cracked, it is all there, and the room and contents unharmed.

The new Custom House, Fig. 10, was practically completed to the third floor so far as wall and steel work was concerned. The

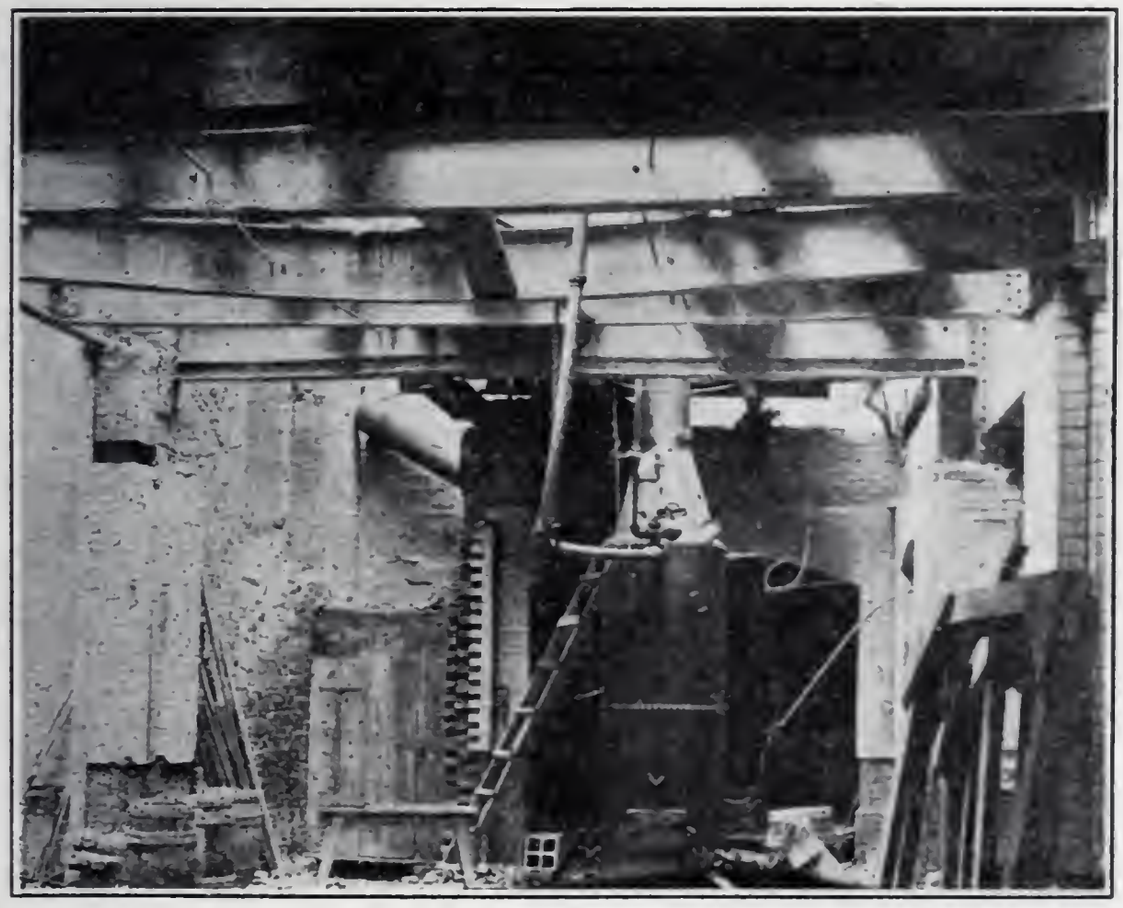


FIG. 10. BASEMENT, NEW CUSTOM HOUSE BUILDING.

construction is of heavy side walls of granite lined with brick, and with steel columns and beams carrying all floor loads. Such planks only as were necessary for walks, etc., were used. Only a portion of this wood work was burned, yet in many places the beams are warped and twisted, and many interior walls show vertical cracks. Such walls were not continuous across building. The cracks were apparently due to the fact that the walls were capable of resisting the expansion of the steel, but not the contraction. A temporary shed was constructed in the basement, housing the hoisting engines, and in its construction one post 4″ x 8″ was strutted up under a steel beam of the first floor. On the first floor adjacent was piled cement. The beams under the pile of cement deflected, while the beam over the wood post is buckled up. The enameled brick where exposed to the flames, flaked off, and gives a dead sound when struck by a hammer, while the common red pressed brick beside it gives a clear, solid ring. The exterior granite is badly spalled, due mostly to the flames from adjoining buildings.

The old United States Store House escaped with little injury. The first story windows are protected by heavy exterior iron shutters. The interior shutters of the second and third stories are scorched, but the exterior glass was not broken. Some sparks entered through the skylight and slightly damaged material stored on the third floor.

The latest of the sky-scrapers in point of construction is the Continental Trust Bldg. We should therefore expect to find this in better condition than the older buildings. Terra cotta was used throughout the interior for fire-proofing. The partitions, vaults and column fire-proofing were of 5″ terra cotta. In order to produce a light and pleasing effect, a light gray face brick was used. It appears that metal clips were used in bonding the facing brick to the main wall.

At the time of the fire, the wind was blowing from the north-west, and the heat from the building itself affected the east wall much more than the west. The result was that the facing brick of the east wall scaled off, and is now in danger of falling off. The practice of borrowing light from the rooms to light the halls was followed here. Most of the rooms were pro-

vided with terra cotta vaults, and the hall partitions formed one side of these vaults. The face of the column fire-proofing lined up with the hall partitions. Furthermore, in many cases, piping was run up the hall side of the columns, cutting down the thickness of terra cotta to one thickness, or $\frac{5}{8}$ of an inch. Such columns seem to be uninjured, although often exposed. It would be interesting to know when this thin column covering gave way, and the present condition of the steel at these points. Many of the vaults were burned, some at least through faulty construction. These vaults were provided with double steel interior doors and single outside doors, all attached to the same steel plate frame. The heat was so intense that few of the outer doors could be opened, and the paint on inner doors was blistered. Brass was melted, and glass was moulded into wavy masses. No sign of wood is visible, not even cinders. The marble wainscoting in the halls is reduced to a granular mass, resembling coarse granulated sugar. The marble treads of the stairs are either destroyed or badly damaged. The steel fascias or lintels were not properly protected, and are badly warped, but otherwise the steel work seems to be in good condition. The cast mullions between the steel fascias just noted are all bowed out, and some are in two pieces, as if they had been burned in two. The expansion of these mullions undoubtedly affected the facias, and just the amount of damage cannot be determined until the floor beams are exposed. Such partitions as were built of terra cotta from floor to ceiling remain in position, but are warped. The cinder concrete filling is lifeless on the surface, but is solid a little beneath the surface. I doubt if there is much concrete used in the majority of buildings in making this filling. The floor arches are in better condition than in most of the other buildings, but the proportional area of floor arches which will have to be replaced, is very uncertain.

Throughout the office buildings were partitions of woven wire or expanded metal, covered with lime mortar. The lime calcine and the metal lies on the floors in grotesque shapes. In the basement of the Calvert building was stored a mass of Mackite blocks, which was found to be lifeless.

In the short time allowed, I have considered typical conditions, and summarize the result in a few words as follows: For the fire protection of steel, the first requisite is conscientious workmanship. Lime or its products have proven worthless. All stone in bulk spall and are not to be trusted. Broken stone in concrete does not act the same as in a solid mass, as evidenced by the floors of the United States Fidelity & Guaranty Co.'s building. Concrete stood the test remarkably well. Terra cotta should be heavier, and under no consideration should it be used in single thicknesses of $\frac{5}{8}''$. For vaults I would recommend that a rich mixture of cement and sand be used for inside and outside, with at least 5" terra cotta blocks forming the core. That good, soft, burned brick will stand fire is without question. Where facing brick is used, it should be substantially bonded to the main wall, preferably with brick. Some kind of shutters should be provided for all exterior windows, and so constructed as to stand considerable heat without giving way. Wire glass offers great resistance to fire, as it is held in position after it cracks.

In the designing of fire-proof buildings, due consideration should be given the probable surroundings before using skylights. All exposed windows should be protected. Elevator and stair wells should be so constructed that they can be cut off from the main part of the building.

Stringent laws are required governing the class of buildings in congested localities and the storage of combustibles. With due consideration of these points, it seems perfectly feasible to construct buildings proof against all ordinary conflagrations.

DISCUSSION.

PRESIDENT—Such a fire as has been described is the crucial test of the engineers' and architects' skill, and we shall be glad to have the engineers and architects give us a full discussion of the subject.

MR. SCHOTTE—The first question which I think we ought to try to answer, and gather facts from which to answer, is how far are we to go in the protection of fire-proof building? As the gentleman remarked to-night, some cases of insurance were settled on the basis that everything above the foundations was a total loss, except the steel frame-work. Now, from the engineering point of

view, to build a fire-proof building, to protect the steel frame-work is a waste. Then the question naturally arises, what conditions are we to assume before designing fire-proof protection? Are we to assume the severest conditions that we know of, or are we just to take ordinary conditions and design most protection against them? I don't care to enter very much into the behavior of the various systems, because I might lay myself open to certain ties, as I am connected with a concrete steel fire-proofing concern, and, of course, naturally, I think that it is the best protection. But yet I believe that this fire has taught us that we ought to design everything in connection with a building in such a way that it will not only withstand fire, that is the destructive action of fire, as all protection does, or the steel and frame-work which it protects, but we ought to design and put in fire-proofing which will withstand shocks from buildings which are not so fire-proof as the particular one we have in mind. The next lesson to be derived is, that our building laws ought to be so changed that in certain districts, especially in business districts, no combustible buildings should be allowed. That is all I have to say.

Mr. Swensson—Having spent a week of observation and study in Baltimore, about a month after the great fire, most all the points, to which attention is called in Mr. Hazen's admirable paper, came under my observation, and similar conclusions and deductions, as to fire protection and fire-proofing of buildings in large cities, forced themselves on the technical observer.

However, being bent on a study of comparison and verification, of observations and conclusions drawn from other serious fires in fireproof buildings, some additional points were noticed, especially in regard to the effect on the steel work in such buildings; effects, which are not noticeable at first glance and under the cover of the still attached but ruined fire-proofing.

The first exhaustive technical investigation and report of the effects from a serious fire, on a large steel skeleton fire-proofed building, was made by three members of this Society in 1897, on the Horne building in this city, for the fire underwriters, and published in the "Insurance World," and in 1898 republished in pamphlet form by "The British Fire Prevention Committee" of

London. This fire, being in a retail dry goods house, or department store, was as fierce and intense as in the office buildings in Baltimore, and the effects on the steel work and fire-proof materials as great. My observations showed conditions to be identical, fire-proofing being largely totally ruined and the steel work badly warped, but not ruined as a material. Thus mostly all fire-proofing in the Baltimore skyscrapers will have to come down, a good deal of the steel work must be taken down and straightened, and some has to be replaced, not because it is ruined, having lost none of its original qualities, but because it will be too costly to straighten.

The report on the Horne building draws a few conclusions, which seem to fit equally well for the Baltimore buildings; it says as follows:

1. "In buildings of about this height the distortion of the steel framework due to the heat of the fire cannot in any instance be sufficient to work any serious damage; nor is it probable that at any time would connection rivets be sheared off. This conclusion is arrived at for the reason that there is no probability that any future fire will be fiercer than the one at issue."

2. "The method of fastening fire-proofing to the underside of beams with sheet iron strips should be discarded."

3. "It cannot be too often reiterated that open front buildings like this should be protected from external fires by metal shutters, and also that all shafts should be provided with metal doors which can be readily closed at all floors."

4. "The most important lesson taught by this fire was the lack of strength developed by the fire-clay fire-proofing. The building was permitted to move in any direction without any material restrictions by the fire-proofing. The floor arches showed by the scaling off of the lower webs that they were unable to offer any sufficient force to counteract the tendency to lateral motion."

5. "The column protection, although composed of the very best obtainable kind of fire-clay tile, was also not of sufficient strength."

"In our opinion it would have been necessary to dismantle the whole steel frame work had this structure been fourteen or fifteen stories high. The leaning at that height at the same proportion

as developed, would have entailed the necessity of taking the whole structure down."

"Owing to the fact that steel columns or girders or beams after being subjected to a long-continued fire will assume the same temperature as fire-proofing, and owing to the fact, furthermore, that the rate of expansion of the steel is much greater than that of the fire-clay tile, destructive movements are permitted which, as shown in this experience, will result in considerable damage, and which damage will increase in direct proportion to the height of the building."

"In view of these important developments, it is our opinion that important structures of this class should have a radically different method of fire-proofing. The fire-proofing should be in itself strong and able to resist severe shocks, and should, if possible, be able to prevent the expansion of the steel work."

"There seems to be but one material which is known that could be utilized to accomplish these results, and that is first-class concrete. The fire-resisting qualities of properly made concrete has been amply proven to be equal to, if not better than, fire-clay tile, as shown by the series of tests carried on by the building department of the city of New York."

"From the experience gained in street railway construction in laying continuous rails, it is to a large degree possible to prevent the metal from expanding. In street railway work this has been accomplished merely by the adhesion of the pavement to the side of the rails. In building construction the same results could be obtained by encasing the columns and girders with concrete placed directly against the steel work. The adhesion of the concrete would to a large degree prevent unequal expansion of the concrete and steel. The floor arches should also be constructed of concrete, but of sufficient depth to be able to resist lateral forces. With the prevention of injurious expansion and the protection of columns with materials that can stand severe shocks of any nature whatever, the modern steel frame constructed building would be more thoroughly protected against fire."

All of the above could just as well have been written of the Baltimore steel skeleton buildings, destroyed in the fire of 1904. It will likely be found in Baltimore, also, that after taking down

the fire-proofing, much more steel has to be taken down than at first anticipated, inasmuch as the fire-proofing used does not protect the steel sufficiently to prevent it warping. In my judgment this is not a case of quality of the fire-proofing as much as it is a case of quality and method of construction of the tile and its application to the steel in the building.

The author, expecting to find the newest building, or latest in point of construction, in better condition than the older buildings, loses sight of the fact that this is an age, and this a country, par excellence, in which economical measures, in point of construction, are constantly expected and adopted, until we often reach the limit before we are aware of it. We all know that clay and clay materials are one of the best refractory substances, but it cannot and should not be in very thin sheets or layers, to best withstand fire. In the early days of skyscraper construction, the tile used had webs of a thickness better calculated to resist fire than those of the present day. This reduction in thickness is due to efforts to decrease the weight of fire-proofing, and in consequence, the steel, required to carry same; all in the line of economy, resulting in less fire-resisting qualities in the latest construction than in the older skyscrapers. This is, to my mind, the most serious criticism against tile fire-proofing, but this reduction of thickness and weight seems to be necessary to compete with the various forms of reinforced concrete fire-proofing.

Wherever reinforced concrete had been used for floor arches and slabs, in the Baltimore buildings, the result showed its superiority over tile construction, if not over brick arch construction.

Old buildings, in which concrete construction had been used in converting the lower floor to bank rooms, were totally destroyed above this floor, the first floor remaining practically in its original condition.

Brick arches in floor construction also stood the fire and protected the steel work from warping, the same as concrete construction; however, judging also from brickwork in walls, the old-fashioned mud-brick, of fine ground clay, proved much superior to the new styles of bricks, such as shale-bricks, etc.

Notwithstanding above facts were readily noticed by the impartial observer, we are surprised to read the contradictory opin-

ions expressed in both the technical and daily papers, as to the superior fire-proofing qualities of present day thin-web tiling.

I fully believe that fire-proof buildings can be constructed with either mud-brick, clay-tiling and concrete for fire-proofing material, but such material must be put on in sufficient thickness to properly protect the steel, and such severe economy must not be practiced, as it is possible to do with tiling, but not with brick and concrete. That metal window frames and sash, wire glass or steel shutters will protect the building from outside attack is proven by the electric power building on the alley, at the point where the fire first started; tile or mosaic flooring, metal doors and furnishings, and lastly metal furniture will protect the inside.

A very good and efficient protection against outside attack is the automatic sprinkler system, as proven by the O'Neil dry goods store on Charles street. This store is housed in a couple of old-time ordinary brick buildings, remodeled, for store purposes. These buildings are fitted up with such sprinklers, and when the fire reached this store the sprinklers were put into action by the heat and the continuous sheet, or wall of water, thus produced, afforded ample protection, the store being untouched by the fire, and its business was not interrupted at all.

MR. TONNELE—Mr. Shotte made a remark I would like to have him explain. He said it seems hardly worth while to protect the iron work and steel work. I don't know just what he meant by that. One more point: Will clay around the steel protect it from the heat sufficiently so that it won't heat up enough to lose its temper, that is to be weakened in the structure?

MR. SCHOTTE—In answer to Mr. Tonnele's first question. If we apply fire-proofing at all, we should buy such fire-proofing that will in itself withstand a fire sufficiently, so that we are not obliged to take it down after the fire has swept around it.

The old style tile, terra cotta and lumber, which you probably all know, was made by mixing a certain amount of saw-dust in the clay, and burned all the saw-dust of it, was very elastic. In fact if you took a slab you could bend it perceptibly before it would crack, and I have seen slabs of that material heated to an extensively high temperature and then thrown into a bucket of water and in quite a number of cases it did not crack, whereas

I have never seen a piece of hard-burned clay, I mean floor tile, which did not crack when heated and thrown into water. So any material, I believe, which is used for fire-proofing purposes must have this quality; must be elastic and must be able to withstand some quick expansion and contraction which is caused by fire heating it up and water being thrown upon it. All concretes possess that to a greater degree than the hard-burned clays. Some concretes possess that to a very remarkable degree.

There is another point I wish to call attention to, something I learned down in Baltimore; and that is that most of these large sky-scrapers were completely destroyed within 15 to 20 minutes from the time the fire took hold of the combustible parts, until the building was entirely cleaned out; and the fire was so fierce there, that hardly any, if any, water ever got near any of the burning offices. It was heat, remember, and that simply did the damage. No water came near it. People could not get near it. Not only was the temperature so great, but the air current was so great that some people told me down there that they had heard of people, and one man told me himself, that he had actually to crawl out of the way and hold to the railings around areas on buildings and steps, there was such a current. On the other hand, the Safe Deposit & Trust Co.'s building had quarter-inch inside steel shutters. I suppose the building is about 80 feet square, or something like that, one room, a bank building. The watchman stayed quite a little while in the opposite end of the building at the time of the fire attacking the front end, until he got out.

MR. SWENSSON—It is rather interesting to know, when considering the effect of the fire on fire-proofing material, that most of the skyscrapers in the Baltimore fire were never touched by water at all, as the heat was so fierce that man could not get near enough to apply water. Some of these buildings were completely burned out and gutted in 20 minutes after the windows were broken and the flames had entered. Not only was the temperature extremely high, even a square or two away from the flames, but the air current was so strong that people could not walk or keep on their feet in the neighborhood of the fire; they had to crawl along the buildings, holding on to railings on steps and around area ways, to get away from the heat and air currents.

Although the heat was so great, a building can be properly protected, as shown by the Brown Brothers & Co. Bank, Safe Deposit and Trust Co. building and others; the latter is a building about 80 feet square, of one banking room only, under one-span roof, and thus rather high for one story, built of good bricks, with front stone-trimmed, inside plate steel shutters and double well separated skylight roof. The building is located in the center of the path of the fire, and although the stone in trimming had melted and spawled, the brickwork was uninjured; the windows broken, but the interior decoration protected, and only slightly smoked, by the steel shutters and double skylight.

PRESIDENT—That question in regard to the injury of the steel, I believe, was asked. The second question of Mr. Tonnele's is: "Would the steel lose its temper?" The steel would not lose its temper until it would be heated above the regulessence point, and at that temperature it would buckle and the building would collapse, and that would not be until it got to be a dull red. It doesn't lose any of its strength at all. In fact it would buckle, if there were any weight on it, before anything else would happen. When it was at that temperature it would be in its weakest condition.

MR. J. A. SHINN—In the report on the Baltimore fire, made by Capt. John S. Sewall, corps engineers, U. S. A., the use of ash concrete for fire-proofing is approved. I have made a number of investigations of this subject, among them being one occupying about six months of time, in 1886, for the purpose of ascertaining the economic value of the boiler ashes made by the New York Steam Company; and another, in 1897, occupying seven months' time, in an investigation of, experiments with, and report upon the domestic ashes of New York city, with particular relation to their quantitative composition and the purposes to which the several parts were adapted to secure the greatest consumption with the best economic and financial results.

The latter investigation was under the direction of Col. George E. Waring, Jr., Commissioner of the Department of Street Cleaning of New York City.*

*Annual Report of Col. George E. Waring, Commissioner of Street Cleaning Department, New York City, for the year 1897.

These investigations demonstrated that in considering the use of ashes for mortar and concrete, account must be taken of the kind of coal from which the ashes are produced, whether bituminous or anthracite; whether produced by low combustion (domestic) or high combustion (manufacturing), and of the several parts of each, fine ashes, clinker, coke and unburned coal.

Domestic bituminous ashes contain a maximum proportion of coal and coke, and a minimum of clinker, the latter being the only constituent of value in the production of a good concrete.

The fine ash of bituminous coal is absolutely worthless in combination with lime for mortar, and positvely injurious in cement concrete in proportion to its relative volume. The coke, whether of domestic or manufacturing product, is too light, porous and friable to produce a good concrete, and such ashes are fit only for such work as cellar floors. Unburned bituminous coal is positively injurious in either lime or cement mortar; the oil and tar being developed by the lime.

Fine anthracite ash of domestic production, when mixed with lime in the proportion of 90 parts ash to 10 of lime, gave tensile strength of 60 pounds per square inch, as soft mortar, and 120 pounds as stiff mortar (Beton), at 28 days, but is injurious in cement mortar.

On the contrary, the fine anthracite ash from boiler furnace is valueless in combination with lime, but is not objectionable in cement concrete in the proportions usually found in such ashes. Unburned anthracite coal, while not being a desirable constituent of concrete, is not injurious if in reasonably small proportion, say 10 per cent. or less.

My conclusions are that bituminous ashes are unfit for concrete where either strength or fire-proof qualities are desired, but that anthracite boiler ashes may be used for fire-proof floors if care is taken to procure those free from an excessive proportion of fine ash and coal.

MR. SAML. DIESCHER—Mr. President, the appearance of the figures we see here, suggest the idea that the materials used for the protection of steel, as well as for the ornamentation of fronts, is not fit for the purpose under present conditions. The fires we have noticed are so intense that these materials can't resist the

expansion and subsequent contraction, or quick cooling; the materials peel off. We see from that picture that where the front is built of granite, or is built of terra cotta, or of sandstone, or of any other material such as pressed brick, etc., it goes to pieces,—it cracks. This suggests to me that the material of the future will be concrete, that is, cement. It will lead to this, it seems to me, and blocks of cement probably will be used instead of blocks of stone. If, for instance, the people who build the houses in Baltimore—they will surely rebuild them, and the question will arise, what material should they use. Now all that granite has to be taken down. It is unfit for further use. They have to put in new granite or some new material. Now would it not be better to use cement blocks, and if the fire occurs again, they can simply put cement on and restore those floors again as they were before. The new faces are put on over the centers, but must stand just as well as the old cement. Another consolation that I draw from the appearance and experience is that the envelopes of the steel constructed are entirely too thin; they would have to be made so thick that they would afford much better protection to the steel. The heat would not damage them so fast as it does now. As the gentleman here showed that case where the column got so hot that the abuttments on the ceiling gave way; we have to draw from this experience that there must be more material put in front of these columns to protect them, and it seems to me that there cement will have to be used, or something else will have to be found; for instance, furnace slag. I don't know how that would behave; I am not a chemist; I don't know how that would work; but whether it would not stand fire better than the modern materials, I don't know. The stones won't answer; we see them go to pieces, and some stones particularly are easy; for instance, limestone is of no consequence whatever.

Mr. Swensson—Questions, in regard to the effect of such fires on steel as a material, have been asked, and our President has well answered same, and in addition, please note the following from Report on the Horne building:

"To determine to what extent the steel had been injured by the fire and what beams could be safely straightened, three very

badly twisted beams were selected and test pieces were cut out as close to the bend as could be gotten. It was surmised by your Board of Engineers that the fire had not damaged the steel, that the store would simply act as an annealing furnace, and that the material would be improved rather than injured. The results of the tests justified the opinion of the Board. Regardless of how badly bent the sections were, the material was in no case injured." Results are given in the following table:

No. of test.	Test piece cut from	Per cent. reduction.	Per square inch. elastic limit.	Max. load.	Exten. %	Fracture.	
1	12-in. Beam Web..	43.8	34,830	58,300	26.25	Ang.	Silky
1	" Top Flange	53.8	41,340	58,850	25.75	"	"
1	" Bot. "	48.5	43,010	62,470	28.75	½ cup	"
2	" Web..	52.9	34,800	58,120	26.75	"	"
2	" Top Flange	47.4	42,060	59,350	24.5	Irreg.	"
2	" Bot. "	63.4	38,160	58,190	27.5	Ang.	"
3	10-in. Beam Web..	45.0	41,750	65,140	25.0	Irreg.	"
3	" Top Flange	49.3	39,500	59,260	23.75	Ang.	"
3	" Bot. "	44.7	40,230	60,100	25.00	"	"
4	4x4x5/16 Angle...	19.5	39,650	52,600	15.0	Fibrous	"
4	" "	21.1	34,850	51,780	21.25	"	"

From the above tabulated results of 26 tests, the conclusion is evident that no injury whatsoever to the steel, as a material, is caused by such fires as at Baltimore; it has rather been made more ductile by the annealing it has received.

Mr. Aiken—I didn't notice anything beyond that which was touched upon to-night, except the one thing that Worthington said he noticed. I had seen the Chicago fire and the Boston fire, and I was impressed with the fact that both of these fires, although they were considered pretty hot, had a great many black ruins; and I was impressed with the white appearance of the Baltimore fire, showing that the heat was greater than anything I had ever seen before.

Mr. Ellis—There is a question in relation to the shutters I would like to ask. Mr. Swensson, I think, mentioned that in one of the buildings there the one-fourth inch shutters on the inside seemed to be a protection. Mr. Hazen drew our attention to one picture there in which he said the shutters had fallen. Now what I would like to know is, whether the so-called fire-shutters we are compelled to put on buildings now are any good?

Mr. Swensson—The fire-shutters, to which the author called

attention, were the Standard Underwriters' fire-shutters, prescribed by law, but in this fire the heat was so great, unusually so, that the wood simply burned out of the tin; so that, although these fire-shutters may be of some use in ordinary fires, they were of very little use in this case. The shutters, mentioned as being on the inside of the windows on the Safe Deposit and Trust Co. building, were solid steel plates, and protected the interior of this building effectually. The paint was burned off the outside of them, after the window glass had broken, the inside paint was badly blistered and some of the shutters had to be taken down and sent to the shop for straightening and flattening, but that notwithstanding they had done their work of protection.

MR. ELLIS—Then can you consider that that fire was too much of a test for everyday practice, or can you say that this fire proved that shutters were of no use?

MR. SWENSSON—I agree with Mr. Aiken, who has already indicated that this fire was no ordinary fire; that it was too hot. But fires of such high temperatures, even if not so extensive, I believe will be more common than formerly, owing to our changed conditions of housing many offices, people and their belongings in one building; greater amount of goods in one store, use of more inflamable goods, etc., from which it can readily be concluded that such sheet-iron-lined wooden shutters are less of a protection than formerly.

MR. WORTHINGTON—There is one other point about those shutters; the Union Trust, the Herald, the B. & O., and the Equitable buildings, all had fire-shutters on one side; but the fire did not strike the building on that side and it is pretty hard to say just how much protection the shutters afforded because the buildings took fire on the sides unprotected by the shutters. They all seemed to be the accepted type of fire-shutters, a wooden body covered with sheet metal on all sides, but there was not much left of them.

MR. SWENSSON—Are you not mistaken about all the buildings? My recollection is that there was one of the buildings which had such shutters directly in the line of the fire. But it makes little difference on which side the shutters were attacked by this fire, because from all accounts the heat both outside and inside of

these buildings was high enough to burn out the wood in these fire-shutters; it was one gigantic furnace of flames sweeping through, around and over the large buildings, by the time the fire reached them.

MR. WORTHINGTON—On two sides only; the front and one side of this building, the Maryland Trust, I refer to, were exposed to the brunt of flames raging just across a narrow street with the wind blowing directly towards this side, which had wide windows with very ornamental terra cotta trimmings; this terra cotta was altogether destroyed.

MR. JAMES—It seems to me there is one point that has been lost sight of in the discussion, and that is the weight of the material which goes into the building. Now if we were to consider the steel frame of the building to be designed and to consider fire-proofing that steel frame with a layer of concrete, I think it will appeal to everyone immediately that the weight of that concrete must be considerably greater than the weight of a coating, of say, 4" terra cotta. It might be that your fire-proofing would weigh double, if it is a sufficient thickness of concrete to be put on, what the fire-proofing of to-day weighs. That would be a very great factor to take into consideration in designing your steel work. Further, the matter of attaching fire-proofing by sheet iron clips, I believe, is almost entirely overcome. There is a detail which is familiar to everybody, I think, who is familiar with construction for covering the under-side of beams, which obviates the use of clips. As to the use of the concrete steel building, I don't think the construction has advanced to the point, at this time, where it is possible to build buildings 24 stories high. I believe the highest building of that kind is a 16-story building in Cincinnati. And I think that, furthermore, the fact that in cases, where only $\frac{5}{8}$" of terra cotta was over the steel work, and the steel work shows, on the first inspection, no serious detriment owing to the fire, in those places it is a remarkable testamentary in favor of terra cotta fire-proofing. I do not mean to uphold terra cotta fire-proofing against the ideas of later concrete, and yet if it had not been for terra cotta fire-proofing, those buildings would have been nowhere to-day. The steel frames would have crumbled and fallen. And

take any building: There is no test in Baltimore, that I saw, of the building of fire-proofing of anything but terra cotta to withstand the burning of very poorly constructed buildings, adjacent to them, and that is something which possibly has not been determined by the Baltimore fire. There are a few buildings in the country.—I know of one in Cleveland,—in which the columns are encased in concrete entirely, which seems to me a very ideal construction, but I don't know that any such building as that has ever been subjected to such an intense fire as that of Baltimore.

MR. SCHOTTE—I presume the last speaker refers to holding the tile on the end of the beam with abridgements of the other tiles. Well, I saw some of that in Baltimore that had that construction in it. The result was that some of it held and some of it didn't. Those little abridgements warmed up and the end part peeled off. It was not as much as in the concrete construction by any means; but yet it was not perfect. I would throw out a suggestion in regard to the weight question, whether it would not be better to double the thickness in the webs—whether that would not give better results. You would have the internal strains in the corners like you have now. Get the webs a little thicker, and perhaps the whole block. Mr. Chairman, I can answer the question before Mr. James' last one in regard to the possible increase in weight. Companies have used fire-proofing beams instead of terra cotta. By using that in between the terra cotta construction, the spacing between the different beams does not exceed very much a span of six feet. In most cases of very large buildings that have come under me, I can say that 4′ 6″ to 5′ is the span mostly used, and the average thickness of flushing tile is about 8 and 10 inches, very seldom 12 inches, except for warehouse purposes. And in a tile construction, the tile weighed from 40 to 60 pounds per square foot. On the concrete, as put in fire-proof buildings, it weighs about anywhere from 80 to 120 pounds per cubic foot, and as a 4″ slab of re-inforced concrete can be safely thrown over a span of about 12 feet for the ordinary office building floor loads, you can readily see where the advantage lies; because you can use less iron. For instance, instead of using say 12″ beams you can use two 50″ beams, which decreases the load, and also the 4″ slab, even though you

increase the protection around the beams to 6 or 8", the saving in dead weight to the whole building is over 25% on the average. As to casing the steel columns so as to protect them thoroughly, I can't, unfortunately, cite you an instance just now where a building was tested by fire. I can tell you an instance, though, a very striking instance, of a building up in Syracuse. I was very highly amused last summer by receiving a letter from an Insurance Company which told us that a certain fire-proof building which we had constructed about a year before had burned down. We were still more amused when they asked us to quote on rebuilding that same building. We investigated the conditions and found that this building was a one-story building with wooden posts, one-story posts about 10 x 10, and I think the building was about 60 feet wide and the roof was just a slippy pitch roof with beams thrown across from column to column and the roof rafters were about $7\frac{1}{2}$ feet apart. The building was designed by a Syracuse architect. The design was not at all ours and we were simply asked to fire-proof according to his designs. And we surrounded all the wood-work and posts and the studs on the outside of the building with metallic lathe and plaster, with about $\frac{3}{4}$ to $1\frac{1}{4}$ inches of cement, one part cement to $2\frac{1}{2}$ parts of sand. This building was used as a storage building for oils and fats and tallows used in the manufacture of candles. There was quite a number of windows in the building. This building had caught fire and the contents burned fiercely all night, at least 15 hours. It burned at least 12 hours before the roof collapsed, showing that those wooden columns were thoroughly protected that it took them that long before they were injured to such an extent that they were not able to carry the roof, which was concrete slabs covered with tar paper. The heat was so intense, because there were at least 60 barrels of fats, etc., and the whole building was greasy that it melted the copper fixtures on that building, melted together the protection of concrete and cement and water in two places. We have several specimens of this at our office. So if an ordinary $1\frac{1}{4}$" protection of concrete can do that for a wooden column for such a length of time, there being no possible chance of the fire brigade quenching the fire, it is very easy to protect steel columns

with concrete. Of course you have to make it of a certain thickness, and my opinion is that you ought to leave an air space between the column and the steel work.

If there is no further business, a motion to adjourn will be in order. Motion made and carried at 10:45 o'clock.

C. W. RIDINGER,
Secretary.

TOPICAL DISCUSSION ON FORMS AND RELATIVE ADVANTAGES OF TEETH IN GEARS.*

MR. SAMUEL DIESCHER—There are chiefly two curves used in designing the shape of gear teeth, namely, the cycloid and the involute. Their uses for this purpose dates back to the first quarter of the last century. Teeth shaped according to cycloidal curves are best for wear, but unless the pitch circles of a pair of wheels so designed meet exactly, the teeth will chafe each other until they create their own shape. The advantage of cycloidal teeth over involutes lies in this, that in the former concave and convex surfaces come in contact which affords a larger area of contact upon which to distribute the pressure than with involute teeth in which all surfaces are convex, and for this reason, the pressure is confined to a mere line of contact, and consequently much more subject to abrasion, than if the pressure were more distributed. However, the involutes too have an advantage over the cycloidals, namely, that in this form of teeth the pitch circles of a pair of wheels may be apart or overlap and yet not affect the good working of the wheels.

In well designed wheels the angular velocity must be uniform throughout the whole devolution of each pair of wheels. The teeth shall be of proper strength at the root, and they shall run without much noise.

Cycloidal Teeth. The curves for these teeth are described by rolling a circle once on the convex and once on the concave side of the pitch circle. The curve thus produced on the convex side of the pitch circle forms the portion of the tooth, projecting from the pitch circle outward, and is called "Ephicycloid," whereas the curve produced inside of the pitch circle forms the lower portion of the tooth, and is called "Hypocycloid." The circles employed in developing these curves are called the

*Paper read before Mechanical Section, April 5, 1904.

rolling circles. The diameter of the rolling circle is of great influence upon the shape and strength of the tooth it produces. The smaller the diameter of the rolling circle, in proportion to the pitch circle, the thicker will be the tooth at its foot, which means also greater transverse strength, and vice versa, the larger the rolling circle, the narrower and weaker will be the foot of the tooth. But, wherever practicable, large rolling circles should be chosen because gears so designed have more teeth in simultaneous mesh, run more quietly, and the line of pressure in the middle position of two teeth in touch is nearer to a tangent, at that point, than with a rolling circle of small diameter. The larger circle that may be used is one whose diameter is equal to the radius of the wheel, for in this instance the profile of the part of the tooth between the pitch circle and the foot circle, becomes a straight line, running radially from pitch line to the center of the wheel, and if the rolling circle were made still larger, then that part of the tooth would be hollowed out and thereby weakened. In wheels that have little power to transmit, and especially if they run fast, the diameter of the rolling circle may be anything less than the radius of the pitch circle, but when the capacity to transmit power is the essential requirement, then the diameter of the rolling circle shall be selected with due regard to strength, first and secondarily to quiet running. If a pair of wheels are of considerably different diameters, it is advisable to use rolling circles whose diameters are about in proportion to those of the wheels. However, this may be done only with wheels for some special machine, for neither of such wheels would work satisfactorily with one of same pitch, but designed with the aid of some other rolling circle. Thus, for illustration: Shops that follow the manufacture of wheels, as their specialty, make all teeth according to a standard rolling circle, whose radius is either a certain fixed fraction or multiple of the pitch, or equal the pitch. Gears so designed will work together no matter from what part of the world they come.

Gears with few teeth, for instance nine, must be designed with a small circle, otherwise the foot of the tooth will be so narrow as to impair its strength. Professor Reulaux, who is a recognized authority on gearing, recommends seven-eighths of the pitch as radius of the rolling circles, and this ratio is adopted by

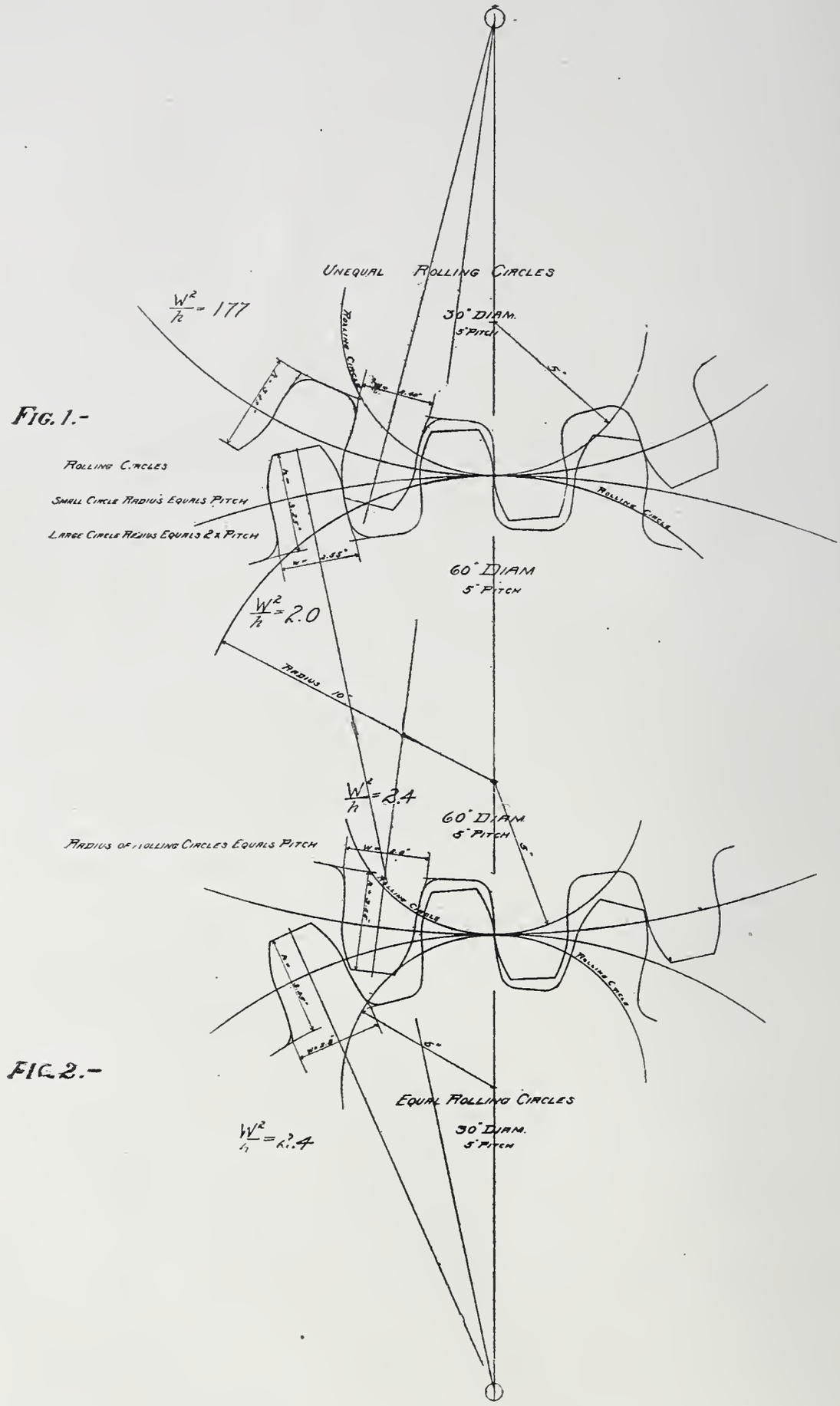


FIG. 1.-

ROLLING CIRCLES
SMALL CIRCLE RADIUS EQUALS PITCH
LARGE CIRCLE RADIUS EQUALS 2 x PITCH

FIG. 2.-

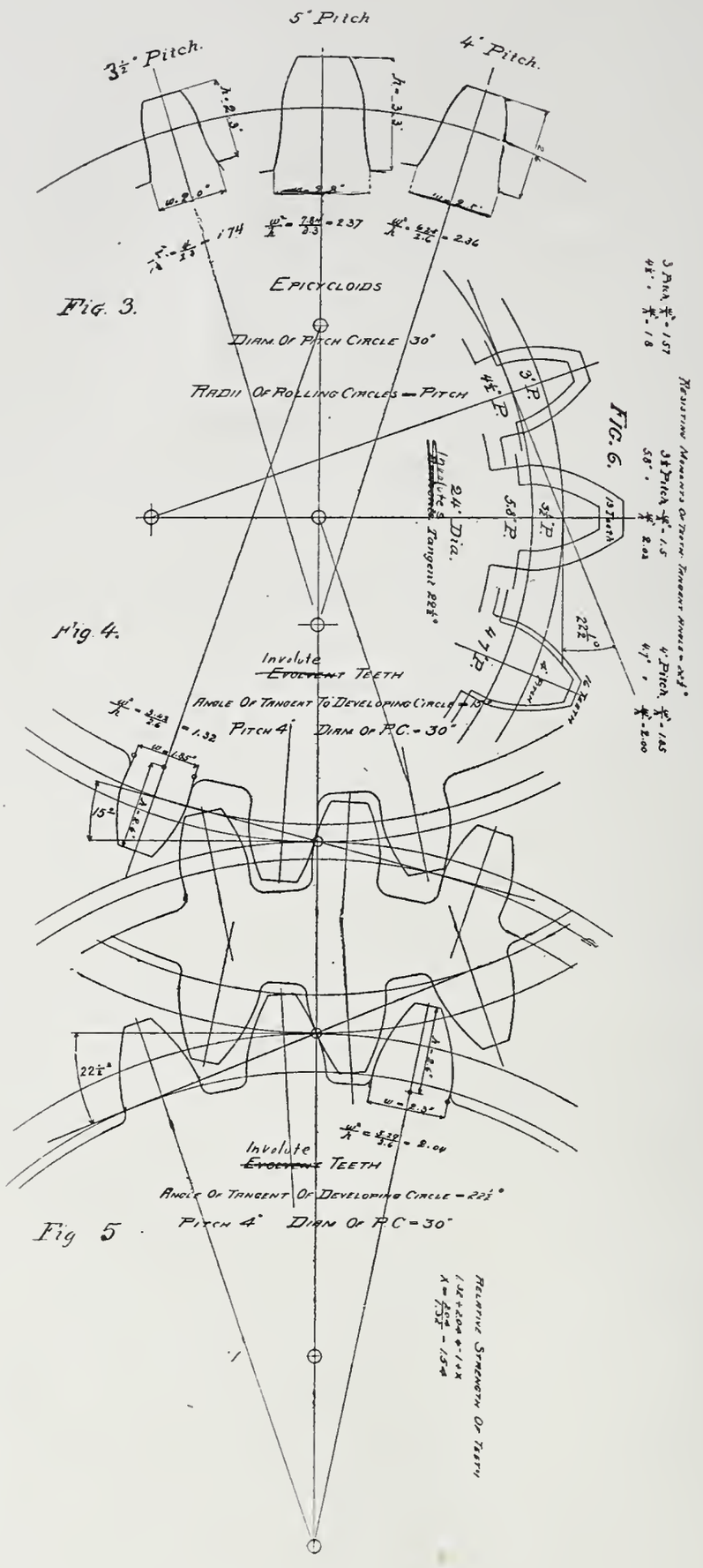
many mechanical engineers and also by specialists in the manufacture of gears.

Fig. 1, of the present drawings, shows a pair of wheels of respectively 30 and 60 inches diameter and 5-inch pitch. The teeth are cycloidal, but made by two different rolling circles whose radii are, with reference to the diameters of the pitch circles, 5 and 10 inches, or one is equal the pitch, and the other is twice the pitch. In using different rolling circles, they are employed in this manner, that the larger one describes the foot portion of the flank of the large wheel, and the upper portion of the flank of the small wheel, and conversely the small circle describes the foot portion of the tooth of the small wheel and the top portion of the tooth of the large wheel.

By examining this pair of wheels we notice first of all, that there are three pairs of teeth in mesh.

Fig. 2 represents the same pair of wheels, as far as diameters of pitch circles and the pitch are concerned, but the teeth of both wheels were produced with one and the same rolling circle. Comparing these two pairs of wheels we find that in the second pair there is only one pair of teeth in mesh, although the pitch and diameters are the same as in Fig. 1. This demonstrates the influence the diameter of rolling circle has upon the shape as well as on the other properties of teeth. The wheels having three pairs of teeth in mesh must run smoother, hence with less noise and less wear than those with only one pair of teeth in mesh.

Fig. 3 shows three teeth on a 30-inch diameter wheel. Each tooth is of a different pitch, namely, $3\frac{1}{2}$, 4 and 5 inches respectively. The rolling circle in each case have radii equal the pitch. In examining these teeth as to their individual transverse strength, we find that the 4-inch pitch tooth is equal in strength to the 5-inch pitch tooth. At first glance this looks odd, but is quite natural, for the coarser the pitch, the fewer teeth are in a circumference, the more will they taper from the pitch circle toward the foot circle, subject to the same rule as stones in an arch, the broader the stone on top, the greater is the angle of taper, and with the coarseness of the pitch grows also the height of the tooth. The transverse strength of a tooth grows with the square of its thickness at the foot and inversely with its height, or bending moment. For


5" Pitch
3½" Pitch.
4" Pitch.
Epicycloids
Fig. 3.
Diam. Of Pitch Circle 30"
Radii Of Rolling Circles = Pitch
Fig. 6.
Fig. 4.
Involute
Teeth
Angle Of Tangent To Developing Circle = 15°
Pitch 4" Diam Of P.C. = 30"
Involute
Teeth
Angle Of Tangent Of Developing Circle = 22½°
Pitch 4" Diam Of P.C. = 30"
Fig 5.

this reason if in any particular instance the wheel diameter is given and a tooth is to be determined on, that gives the greatest strength with the greater number of teeth in the wheel, it will be necessary to try and figure, and not to rely upon the thickness of the tooth in the pitch lines for that is deceiving.

Fig. 4 represents a pair of wheels with involute teeth. The wheel diameters are both 30 inches and the pitch is 4 inches. The angle of the tangent of the developing circle is 15 degrees. This angle is almost universally adopted as the standard tangent angle for developing circles, and it has precisely the same influence upon the harmonious working of involute teeth as the rolling circle in relation to cycloidal teeth. By examining these teeth we find here, too, that only one pair of teeth is in mesh. Of course, there are positions of the wheels in which two pairs will mesh, but only for a short interval. However, for comparison, we must note that all of the wheels here shown are represented as standing in a middle position, that is, a line drawn through the two wheel centers, passes also through the point of contact between one pair of teeth. As to the comparative transverse strength of cycloidal and involute teeth of same pitch, 4″ in wheels of same diameter, 30″, we find by a calculation that the strength of the cycloidal tooth is to that of the involute tooth as 2.36 is to 1.5.

There are occasions when wheels of especial strength of teeth are required, for instance, in rolling mill gearing, particularly in mill pinions. The latter are usually designed with very coarse pitch with the aim of insuring great strength. For the reason of heavy wear in the bearings and journals of mill pinions and the contingent parting of the pitch circles from each other, the involute teeth are more satisfactory than those of cycloidal form, but in order to impart to those teeth greater strength than standard teeth would have, the angle of the tangent to the developing circle is made greater than 15 degrees. Thus in some of the large plants about this city, an angle of 22½ degrees is adopted as the standard for mill pinions, and at the Carnegie Mills, as much as 28 degrees.

In Fig. 5 we see a pair of 30-inch wheels with 4-inch pitch, and 22½ degrees angle of tangent. By comparison we see that these teeth are much stouter than the same teeth at a 15-degree

angle, though every other dimension is the same in both cases. We find also that here, too, only one pair of teeth are in mesh. Furthermore, we find that in Fig. 5 the line of pressure through the point of contact is much less normal to the line drawn through the wheel centers than in Fig. 4, and therefore a greater pressure is exerted toward the journals and bearings than in the former instance. Concerning the strength it is to be said, that according to calculation, the strength of tooth in Fig. 4 is to that in Fig. 5, as 1.5 is to 2.3, or the tooth in Fig. 5 is by 53 per cent. stronger than that in Fig. 4.

In Fig. 6 we see 6 involute teeth in a 24-inch diameter wheel and angle of tangent is $22\frac{1}{2}$ degrees. These teeth are of different pitches, namely, 3, 3.5, 4, 4.5, 4.71 and 5.8". The latter pitch corresponds with 13 teeth, the standard number adopted for all mill pinions in one of our largest manufacturing plants in Greater Pittsburgh, whether their diameters are large or small. It is difficult to see why any fixed number of teeth should be adopted for all sizes of wheels.

The pitch 4.71" is introduced here for comparison because it gives 16 teeth against 13 of the 5.8" pitch. A wheel with 16 teeth runs smoother than one with 13 teeth. The strength is determined by the quotent derived by dividing the square of the thickness of foot by the height of the tooth. Accordingly the relative strength of these teeth are as follows:

3" pitch, 1.57; 3.5" pitch, 1.50; 4" pitch, 1.85; 4.5" pitch, 1.80; 4.71" pitch, 2.0; 5.8" pitch, 2.02. Hence 4.5" is to 5.8" as 1.8 to 2.0 and 4.71" is to 5.8" as 2.0 to 2.0.

The pitch of 4.71" gives 16 teeth of same strength as the teeth of 5.8" pitch, of which there are only 13 teeth in the wheel of same diameter as that of 16 teeth.

CHAIRMAN—Gentlemen, I would like to have somebody start and say something in favor of one or the other system, so that we can get right down to discussion. What is here seems to be cycloidal.

MR. DIESCHER—There are only two well known systems employed and every engineer uses both systems, according to the requirements of the occasion.

CHAIRMAN—Some prefer one or the other system. I know

there are a great many people who have very decided opinions about cycloids and involutes, and I would like to hear them.

MR. DIESCHER—If wheels were always kept in such adjustment that any wear in the journal bearings would not alter the distance between the centers of the shafts of a pair of wheels in mesh, then the cycloid tooth would be preferable to the involute tooth, because it has the characteristic property that its shape is made up of both convex and concave curves, so that when two such teeth mesh, there is nearly always a convex curve in touch with a concave one, and vice versa, owing to which there the area of contact is larger than with the involute teeth that are made up entirely of convex curves and, therefore, afford only very small areas of contact.

MR. FLANAGAN—I would like to ask Mr. Diescher, referring to that figure 1 of his, that shows three teeth in mesh,—Do these three teeth remain in mesh in all the different positions that the wheels assume in relation to each other?

MR. DIESCHER—It seems not, but it is already a decided advantage to have two pairs of teeth in mesh instead of only one.

CHAIRMAN—One can tell quite readily from the drawing of a pair of gears, how many teeth will be in mesh at one time. Take, for instance, the cycloidal gears. On the line of centers construct the rolling circles, also draw the addendum circles, indicating the height of teeth above pitch circle. Then the axis of the two rolling centers intercepted between the addendum circles show the path of contact of the teeth. If the length of axis slightly exceeds the pitch, then two pairs of teeth will always be in mesh, and if it exceeds two times the pitch, then three pairs of teeth will be in mesh.

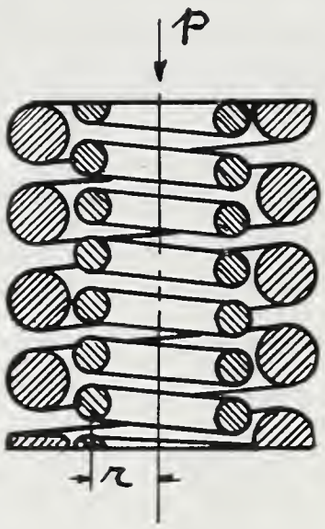
For involute teeth, the procedure is similar. In this case the path of contact is the length of the line of obliquity intercepted between the points, then the addendum circles cut the line. If this exceeds the pitch, then two pairs of teeth are in mesh.

NOTES AND CONSTANTS ON SPRINGS.*

MR. STUCKI—The following remarks are intended to establish limits and constants so as to enable the designer to choose such dimensions which are most advantageous to the steel manufacturer, the spring maker and the user as well.

HELICAL SPRINGS.

The fundamental formulas are well known, and are as follows:



$$p = \frac{16\,r}{s\,\pi\,d^3}$$

$$f = \frac{32}{\pi} \times \frac{2\,\pi\,r\,h}{d} \times \frac{p\,r^2}{g\,d^4} \text{ or } \frac{64\,p\,r^3\,h}{g\,d^5}$$

The load "p" is in direct proportion to the fibre stress "s." The maximum load corresponding with the maximum allowable fibre stress is also called the capacity of the spring.

The load is also in direct proportion with the deflection "f," and great care should be taken that the maximum load corresponds with the maximum deflection, which is the difference between the free and solid height. If this difference, or total motion, as it may be called, is too great, the spring when compressed solid will be over strained, and if too small, the real strength of the spring is not made use of, which is equivalent to a loss in material pure and simple.

*Discussed by the Mechanical Section, April 5, 1904.

The maximum stress "s" should be taken as 80,000 lbs., and the stress under the static working load should not be allowed to run up over fifty thousand pounds per square inch.

The modulus or torsion "G" taken as 12,600,000, and recommended by Mr. Cloud (Trans. A. S.-M. E. V. 173), has given very good results, and springs designed in this way have been manufactured a good many years without any complaint from the manufacturer's side. Neither have I heard of any serious trouble in service, which is going to show that the requirements of such a design can be met successfully by the open hearth product. All the car springs adopted by the Master Car Builders' Association are based on this figure.

Although a spring maker assured me that a bar of 2" diameter could be hardened without the slightest difficulty—the heaviest bar used in railroad service up to date is $1\frac{5}{8}$", and it stands to reason that unless the designer is absolutely compelled to—the diameter of the bar "d" should not exceed this figure.

The minimum radius "r" should at least be $1\frac{3}{4}'' \times$ the diameter of bar to make a successful winding possible.

The length of the bar is $\frac{2 \pi r h}{d}$ which is to be used in figuring the weight. After the bar is tapered the length is $\frac{1}{2}$ of a turn or $\pi r h$ greater without however having changed the volume any. The solid height being "h" the free height naturally is $h + f$.

In the case of double or triple coils, it is essential that the different coils work in harmony with each other—that is to say, the fibre stresses in the different coils should be alike no matter to what extent the spring may be compressed. All should become solid at the same time, at which moment the fibre stress should be 80,000 pounds, and in order to obtain such a result, it is absolutely necessary to comply with the two following conditions:

Large diameter: small diameter=large radius: small radius.

Length of large coil=length of small coil.

These are the proportions for a double coil, and if a third one is used, the second and third coil as a pair again must meet above requirements.

Generally speaking these rules may be expressed as follows:

The proportion between diameter of bar and radius of coil must be the same in all concentric coils.

The length of bar must be the same in all concentric coils.

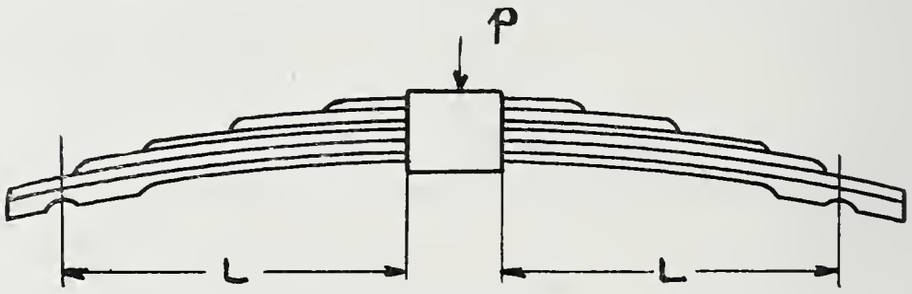
It is of course understood that slight variations have to be allowed so as to be able to specify bars of such dimensions which are easily obtained in the market.

It is also understood that under certain conditions some of the coils are kept out of action until the spring has compressed a certain amount. They are then called graduated springs. For instance, under some stock cars springs are used, the outer coils of which have strength enough to carry the cattle and to provide for an easy riding motion, but when the car on its return trip is loaded with pig iron or other heavy material to its full capacity, then the inner coils also come into play. In springs of such a nature, no harmonious working can be looked for, and the best we can do is to see that the maximum fibre stress is reached in both of the coils at the same moment.

The clearance between the different coils is usually made 1/16" all around. This has proven to be sufficient to compensate for irregularities in the different coils.

ELLYPTICAL SPRINGS.

The theoretical formulas—old in themselves—are:



$$p = \frac{s \cdot n \, b \, h^2}{3 \, l}$$

$$f = \frac{3 \, p \, l^3}{E \, n \, b \, h^3} \text{ or } \frac{s \, l^2}{E \, h}$$

The load "p" is proportional to the fibre stress "s," also to the deflection "f." The load, corresponding to the maximum allowable fibre stress, is called the capacity of the spring.

"L" indicates the length of the leaves from the bands to the supports under load.

Some writers have included in this dimension 1/6 and sometimes 1/4 of the band. However, no reason for such an action has been brought forward except that the band may not fit tightly.

There are other disturbing elements in an ellyptical spring which cannot be well defined by figures, such as the friction between the leaves, the stiffening effect of more than on "full length" leaf, and the variation in the length as the spring deflects. Therefore, the question of what is the correct length, depends entirely upon circumstances. "L" as above given is more correct than if a fraction of the band would be included. It is easier obtained and has held out admirably well in practice.

"E," the modulus of elasticity, is governed by the original condition of the steel and the manner of hardening same. 25,400,000 has been used by the Railroad Company with whom I was connected for years, and it in connection with "I" as above, has given very good results.

It is, of course, easy enough to figure on a higher "E," and it is also easy enough for the manufacturer to harden the steel accordingly, but this point should be carefully watched and a proportionately higher grade of steel must be used, else the material is liable to break under severe service.

For this very reason we should design the springs so that open hearth steel can be depended on, instead of being compelled to look for a higher and more expensive grade of crucible steel. By doing this, the consumer, the spring maker, as well as the steel manufacturer, will be benefited.

Ordinarily 1 per cent. carbon steel with an elastic limit of about 80,000 lbs. is used. By hardening the material, this elastic limit naturally is greatly increased, also the ultimate strength. And I am sure that some of our friends in the steel business can show us some results obtained by tests in this direction.

The fibre stress "s" as a maximum should not exceed 100,000 lbs., and the working stress under statis load should not exceed 65,000 lbs., if there is room enough for such a spring. If higher stresses must be used, the grade of steel must be closely watched.

One writer used different stresses in different thicknesses of steel, allowing 90,000 lbs. for steel $\frac{1}{4}$" thick, and 75,000 lbs. when

$\frac{1}{2}''$ thick. I fail to see the reason for such a sliding scale as there exists no difficulty in working $\frac{1}{2}''$ bars properly all the way through, especially if rolled at the proper heat. Slight variations will, of course, exist, but they should be so small, so as to be negligible in practice, especially since there are so many other factors, causing variations in the quality of the material. The stresses, 90,000, as well as 75,000, are entirely too high. 65,000 would be much better, so that the material can be obtained from the open hearth furnace. There are, of course, exceptions where higher fibre stresses and a higher grade of steel will have to be resorted to.

A number of leaves running the full length is taken as 1/4 to 1/5 the total number "n." The rest should be made so as to terminate in equal steps.

The load deflection and thickness of leaves being in straight proportion—charts have often been made to show graphically these relations, also tables have been published to this effect. However, the formulas are so simple that accurate figures can be obtained very quickly.

The thickness of the leaves "h" as a rule is not made over 9/16" thick, so as to insure an equal temper all the way through. Width of band is made about 1/10 the total span of spring.

In the *Double Ellyptical Spring,* the bands should be made to touch at the moment the fibre stress reaches the maximum allowed. The deflection in this case is naturally twice as great as given in the formula.

G. R. Henderson published extensive spring tables, and Mr. Gaines in the "American Machinist" of July 20th, 1899, published some constants.

MR. METCALF—Mr. President, I am very glad to learn that they have gotten the right way at last. When they first adopted the round bar, the Pennsylvania Railroad used a formula which made springs about 33% too strong. They claimed it was the fault of the steel, etc., as they worked it out very exactly; and I always had a profound respect for formulas. But we took a 6 x 8 spring that worked too strong. In the first place, I did not believe, and I do not believe yet, that the total stress in a spring is given by any formula, because if you figure out the amount of stress that is

given, assuming that that is all compressed by the torsional strain, it means a stress which I think is not possible. That first aroused my doubts. So we put the spring in the testing machine, cleaned the bearing plates nicely and marked the ends of the spring on the plates and closed it down, supposing that the ends might slide around and relieve the strain in that way; but they didn't move. That didn't explain it. Then we laid the spring up again and marked the exact diameter of the spring on the plate on the two sides and then closed it down again and found that the spring had bulged about a quarter of an inch; in other words, we had pressed out a 6″ arch an eighth of an inch. That accounted for the excess of strength that was in the spring that the torsion would not account for. There was another difficulty in the formula that was got over. That was a claim that was made in the original papers read here in Pittsburgh before the Society of Mechanical Engineers. The paper closed with the statement that the modulus of elasticity of mild steel and high steel and wrought iron were all the same, and the assumption was that if you got the spring bar of the right size and worked it out on that formula, it did not make any difference what material it was. After some months, however, when the specifications finally came out, I asked why it was 90 to 110 carbon steel was used when wrought iron would have answered the purpose just as well in the formula. "Oh, the elastic resilience of the high steel was better." However, although these formulas do make a fair approximation, I found the only satisfactory way in which I could get out a right spring was to try it. The largest bar I ever used was $1\frac{3}{4}$″ in diameter. That is a pretty large bar. That spring, I think, was over 12″ in diameter. Mr. Stucki said he did not see why there should be a lower limit of strength put on a $\frac{1}{2}$″ bar than a $\frac{1}{4}$″. There is, I think, a very good reason for that. And that is that if you get up in the size of steel, you increase the strain in the bending, and you are not as safe in the thicker materials as you would be in the thinner. If you consider a watch spring and the weight of the resilience it drives, and then calculate from that up to a spring, say $\frac{1}{2}$″ thick and 4 or 5″ wide, and then tried to use that great big spring to drive a motor of the same relative weight, you would find it would not do it. I think there is good reason,

then, for a modification. I don't know that the amount you have mentioned is correct, but where there is so much strain in hardening the bars, I think that there is a difference. The chief difficulty in springs is not in the designing or in the preparation, it is in the manufacture. That is where the great trouble lies, and as the gentleman says, a good open hearth steel is good enough for any practical purposes. When you consider the first specifications that the Pennsylvania Railroad made, they limit the spring steel from 90 to 110 carbon. I thought the limit was too narrow, but I could not prevail upon them to change. Now that close limit is right for elliptic springs; and I see that they have modified their specifications for coiled springs, and they now allow steel of any carbons, from 70 up. This was done to give the spring maker freedom and to enable him to use judgment. There is nobody living, or ever did live, that could make uniform springs out of steel from 70 to 110 point steel, if the carbons are mixed together. If the spring maker gets his 70 carbons right, he is bound to have his 120 or 140 carbons too hard, if the men that furnish the material furnish it in mixed lots. It does not cost one cent to keep the carbons sorted and to put all of one carbon one size, and then if he has to make a change at all it won't hurt the spring maker, if he knows of the change. We have one customer and we can send him springs from 70 up to 130 or 140 carbons, but we never send it to him mixed. If we have to make a change we keep the lot entirely separate and notify him that that lot is a certain carbon. Now the railroads that don't make any specifications will get that variety of carbons in their springs and you will see what a muss they will get into. They don't know anything about their elasticity or anything else. That is where the chief troubles come in. Then there are other troubles caused by the spring makers; a good many of them abuse the steel. I see it particularly in the railroad shop. The spring steel is abused in such a way that I do not wonder they cannot keep the locomotives on the road; and if you would walk through their spring shop, if you know the business, you could see that the springs ought to break. The engineer now comes in and he is practically in as bad position as any of them, or worse. He has got his principal on one side who wants everything as economical as he can get it,

and the purchasing agent always wants the cheaper things and goes into the market and accepts the lowest bid, and the engineer finds himself between the devil and the blue sea. He don't know where he is And that affects the springs of today, and they simply ought not to be good. Makers are not charging enough to make decent springs out of them.

A few months ago, I read a paper before the American Society for Testing Materials, in which I have treated this subject more fully. It was published in "Engineering News," July 30, 1903.

MR. STUCKI—Mr. Metcalf does not seem to trust the formulas for helical springs. However, the designer must have them. If the maximum fibre stress is such, so that the steel manufacturer can meet the same with his merchantable open hearth product, and if the modulus of elasticity is chosen so that the spring maker does not have to temper beyond a safe limit, there is nothing in the formula unknown or complicated, and it is just as correct as any other formula for shafts and axles subjected to torsion.

The bulging of the springs under the load is natural and absolutely necessary owing to the fact that the length of the bar forming one turn is longer than the circle of the coil radius. The steeper the pitch the greater this difference. If the pitch is reduced by the load coming on the spring, the bar itself does not contract in length, and necessarily will form a larger circle.

MR. METCALF—When the springs were first made, they came out too strong. We reported that fact and then to justify ourselves, to make sure, I had a lot of bars rolled with very great care, from the exact diameters that the formula called for, cut to the correct length, and I saw to the hardening myself, and they were about 33% stronger than the formula called for, and then we gave the springs to the railroad and told them to test them themselves and the result was, the size of the bars were all cut down to suit the facts.

MR. STUCKI—The fact that the springs Mr. Metcalf spoke about were 33 per cent. stronger than the formula called for, indicates that the modulus of torsion "G" was not in accordance with the temper of the springs or vice versa. 12,600,000 are now used on all the standard railroad springs throughout the country, and I have not heard of any complaints from the spring manufacturer on this score.

MR. METCALF—Well, there is no question about it, if you go hardening a piece of steel perfectly, uniformly, it would not make any difference then whether it was a quarter of an inch thicker or a foot long. But if you would look at any spring bar that has been pretty accurately tempered, you will find a ring, right around the outside, probably a 1/16 to a 1/8" thick. The steel is hardened in that far. As you go on into the bar, you will find it a very different grain and very much softer. Now, no man living can harden a 1½" bar all the way through. If you take a bar ¼" thick and take a nice proper hardening heat on that, you can harden that through pretty fairly. If you take the same bar and diameter, ½" thick, it will not be uniformly the same hardness through as the ¼" bar.

MR. STUCKI—As to the necessity of allowing a different maximum fibre stress in the elliptical spring due to the slight variations in the thickness of the leaves as now existing on car, tender and locomotive springs, I may say that there would be more reason for a sliding figure covering the modulus of elasticity as the hardening and tempering is very much more affected by a difference in thickness than the ultimate strength. However, the spring maker up to this time has had no difficulty to overcome this apparent trouble; at any rate during the last 15 or more years I have been designing springs I have never heard of any complaint or suggestion to this effect.

I am also convinced that the steel manufacturer can furnish a nearly uniform material even if the thickness varies slightly, and I have never heard of the slightest difficulty in this direction, and the thickness of the leaves is usually kept below 9/16", not on account of the rolling, but on account of the hardening and tempering process. These two processes affect mostly the modulus of elasticity, and not the ultimate strength of the material.

CHAIRMAN—The point I want to touch upon is, when I have springs designed I use a higher modulus of torsion the smaller the diameter of the rod is. For a ⅛" spring I would use 14 millions, and getting up to 1½" bar I would use the 10 millions. The same in the stress; I would not allow as high a stress on the larger diameter as on the smaller. As Mr. Metcalf says, the small steel is hardened all the way through, whereas the larger bar is only "skin-hardened," you might say.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's room, 410 Penn Ave., Pittsburg, Tuesday, April 26, 1904.

Section called to order by the chairman at 8:30 P. M., 25 members and visitors being present.

Minutes of the previous meeting read and approved.

The subject for discussion was "Coffer-dam Construction." The discussion was participated in by Messrs. N. S. Sprague, C. E. Bennett and S. J. Affelder.

On motion Section adjourned at 10:15 P. M.

WILLIS WHITED,
Sec. Structural Section.

COMMERCIAL GAS ANALYSIS WITH STATIONARY HEMPEL APPARATUS.*

BY H. C. BABBITT,

East Pittsburgh Gas Works.

The apparatus about to be described was designed by Mr. Wm. J. Knox, of Pittsburg, Pa., and has stood practically unchanged for several years.

To a horizontal frame, near to and parallel to the edge of the working-bench, is attached a horizontal rod (D), about $\frac{5}{8}$" diameter, on which the pipettes may be suspended from appropriate hooks attached to the frame of the pipette; while to a vertical rod, secured to frame and bench, are fastened the burette and leveling-tube in such a manner as to permit free lateral motion. The prolong of burette is bent at right angles to the burette and parallel to the graduations. The capillary tubes of the pipettes are also bent to 90°, so that only a rubber connection is necessary to attach to burette. At the top of the burette is a 3-way cock (A), the second outlet (e) being the stam of cock. At the bottom of the leveling-tube is a cock (C). Burette and leveling-tube are connected by a Y-tube to one branch of a 3-way cock (B), the other branches of which are connected, respectively, to an overhead reservoir and drain.

The *modus operandi* is as follows: With (C) closed, open (A) to burette and fill burette with water by opening (B) to supply. Close (A) and attach sample bottle to prolong of burette. Pass enough gas through (e) to insure complete elimination of air. Open (A) to burette and draw in sample by opening (B) to drain. To obtain the volume at atmospheric pressure; with (A) closed, open (C) and, by admitting or withdrawing water by means of (B), the level of burette and tube is easily obtained. With (A) still closed, attach the appropriate pip-

*Paper read before the Chemical Section April 21, 1904.

ette to the prolong of burette; open (A) to burette and force gas into pipette by filling burette with water by means of (B). When absorption is complete, return gas to burette by opening (B) to drain; then level as described above. It it is desired to shake the pipette, a swinging motion may be given to it without disconnecting from burette. The rod (D) is long enough that the hanging shelf, on which the explosion pipette and mercury reservoir are placed, may be thrown back out of the way, when not in use.

The ordinary absorbents are used in the following order:

Potassium hydrate solution (1.27 sp. gr.) for CO_2.

Bromine solution for C_2H_4. A saturated solution of Br in water in a compound pipette for liquids.

Pyrogallic acid or phosphorus for oxygen.

Pyro solution is prepared by dissolving 30 grms. Pyrogallic acid in 75 c.c. of water, transferring to compound pipette and filling the pipette with KOH solution (1.27 sp. gr.).

Phosphorus pipette is prepared by filling a simple pipette for solids with sticks of phosphorus about 3/16 diameter, and then filling with water.

For all oxygen below 50% I prefer the P solution, which is cleaner to handle and equally rapid to Pyro.

Cuprous Chloride solution, either acid or ammoniacal, for absorption of CO, but the ammoniacal solution must always be used if palladium combustion is to follow.

Acid solution of Cuprous Chloride is prepared by making a saturated solution of CuO in HCl (1. 1 sp. gr.) and allowing it to stand over an excess of copper, out of contact with the air, till $CuCl_2$ is reduced to Cu_2Cl_2 and solution is colorless. It is then transferred to a compound pipette, for solids, in which are several rods of copper.

Ammoniacal solution of Cuprous Chloride. (Hempel.) 10.3 grms. of CuO are dissolved in 100-200 c.c. HCl and allowed to stand, out of contact with the air, over copper, till the solution is colorless; it is then at once poured into a cylinder containing from 1500-2000 c.c. water, to precipitate the white Cu_2Cl_2. As soon as the precipitate has settled, decant as closely as possible and wash the precipitate into a 250 c.c. flask with 100-150 c.c.

of water. Then pass ammonia gas through the solution, taking care that no air is introduced, till the Cu_2Cl_2 is dissolved and the solution is a light blue color. Fill compound pipette and dilute with water.

This latter solution is also absorbent for C_2H_2.

PALLADIUM COMBUSTION FOR HYDROGEN.

If this is used, care must be taken that the palladium is active and that the temperature does not run too high, otherwise more or less of the CH_4 will be burnt. During the combustion, the palladium tube must be immersed in a beaker of water at 90° to 100°C. Several authorities state that the tube may be held over a small naked flame, as long as the tube is kept below a dull red. This is wrong, for in spite of the greatest care, local heating will take place and more or less CH_4 be decomposed. The writer is not an advocate of palladium combustion because: 1st. It complicates the determination and apparatus, requiring a support on the upright for the beaker, and wastes time in setting-up. 2nd. The palladium needs regeneration after a very few determinations. 3rd. Under ordinary conditions it accomplishes nothing but what would be obtained by the subsequent explosion, which immediately follows.

Explosion for CH_4, or CH_4 and H_2.

To the residual gas is added an excess of oxygen or air and transferred to the explosion pipette over mercury; the end of the capillary is clipped, and, without disconnecting from burette, the gas is "sparked," returned to burette and contraction noted, passing over KOH and absorption read.

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$
$$H_2 + 1/2O_2 = H_2O$$

From these reactions it will be seen that the CO_2 formed, equals the CH_4 present. If CH_4 alone is present, this absorption will be one-half of the combustion. If H_2 is also present: $CO_2 = CH_4$, and $H_2 = \frac{2C - 4 \text{ absorp.}}{3}$. This is an acurate determination, and from it will be seen the usefulness of the palladium combustion, except when other hydrocarbons are present or

suspected so that from the absorption of CO_2, contraction, and oxygen consumed the composition of the gases is desired. In fact, it is unnecessary to absorb CO for, by absorbing the unused oxygen, the nitrogen is determined and we have as known factors the sum of CO, H_2, and CH_4=A; the contraction=C; and the KOH absorption=D. Three known factors from which the three unknown may be obtained by a simple alebraic solution.

$$H_2 = A - D$$

$$CO = \frac{3A - 2C + D}{3}$$

$$CH_4 = \frac{2C - 3A + 2D}{3}$$

If benzine be present it would be absorbed by the Br. The method used of absorbing in 1 c.c. over mercury before the KOH absorption gives erroroneous results, for the benzine is not completely soluble in it, while the CH_4 and other hydrocarbons are partially soluble.

Dennis & O'Neill (Jour. Am. Chem. Soc., Vol. LVIII, page 395) show that an absorption by an ammoniacal solution of nickel nitrate following the KOH remove the benzine perfectly, without interfering with the subsequent absorptions. This solution is prepared by dissolving 25 grms. crystals of nickel nitrate in 50 c.c. water and 50 c.c. ammonia, and diluting the 150 c.c. with ammonia. This absorption is always followed by a 5% H_2SO_4 solution.

Producer and blast furnace gases carry no C_2H_4 and but trifling amount, if any, of CH_4; so, if the gas is being analyzed for its calorific value, the following procedure will determine it with sufficient accuracy in less than ten minutes.

Absorb CO_2 and O_2 by the proper reagents, add oxygen, transfer to explosion pipette, explode, noting contraction and KOH absorption.

CO_2 formed=CO; $H_2 = \frac{2C - CO_2}{3}$. The sum of the H_2 and CO x 320=B. T.. U. per cu. ft. If CH_4 were present and ignored, the calculation being made as given above, CH_4 would appear as equal volumes of H_2 and CO, thus introducing an error of 3.52 b. t. u. for every per cent. of CH present.

The following values are used in calculations:

C_2H_4	=1560.1	b. t. u.	per	cu. ft.	at	68° F.	=.07292	lbs.	per	cu. ft.
CH_4	=993.55	"	"	"	"	"	=.041669	"	"	"
CO	=320.9	"	"	"	"	"	=.07292	"	"	"
H_2	=320.5	"	"	"	"	"	=.00521	"	"	"
CO_2	=.....						=.11459	"	"	"
O_2	=.....						=.083338	"	"	"
N_2	=.....						=.072920	"	"	"
Air	=.....						=.075098	"	"	"

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The regular monthly meeting of the Engineer's Society of Western Pennsylvania was held in the Lecture Room of the Society's House, at No. 410 Penn Avenue, Pittsburgh, Pa., at 8:20 P. M., May 17th, 1904, President James M. Camp in the chair and thirty-five members and visitors present.

The minutes of the last regular meeting were read and approved.

The Board of Directors reported that they had passed favorably on the following application, and present same to society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
A. RUILOBA,	Engineer, with United States Steel Corporation, 71 Broadway, New York, N. Y.	S. B. Ely, J. M. Davison, M. W. Hogle.

PRESIDENT—The minutes will stand approved. The applications for membership seems to be on the wane. The fact that we almost doubled our membership in the two years previous to this is proof of what united effort will do, and the fact that we are not doing that now is proof that there is not such united effort. It is very desirable to have this good work continued in the future the same as it has been in the past, to add to our roll those men that will do ourselves and themselves honor by joining with us. If there is no further business we will have the pleasure of listening to Mr. C. M. Canady on the subject of "Highway Bridges."

HIGHWAY BRIDGES.

BY C. M. CANADY.

The subject for this evening being a general discussion of highway bridges, it seems proper to devote this paper to a review of the various types of this class of structure and the successive stages of development, both in general design and detail, through which they have passed. It is not the intention to begin with the early dawn of history and elaborate these observations into a study of civilizations through its bridges, but simply to call atten-

tion to and comment here and there upon some of the types and details which have claimed the attention of the designer and manufacturer during the past fifteen or twenty years.

Of the combination bridges, composed of wood and iron, the Howe truss affords probably the best example of the bridge builders' art. These bridges, dating from a time when timber was both plenty and cheap, and of good quality, and iron was expensive, were quite naturally constructed of a minimum of iron and a maximum of wood. The vertical members of the web system, the angle blocks, packing rings, bearing plates, bolts and washers constituted about all the iron parts necessary for the construction of a highway bridge of this type. In a structure so replete with interesting features, it is difficult to single out any one or two points more prominent than the others, that could be more than touched upon in a paper of this kind. Compared with the steel structure of the present day, at least one point in the general design is conspicuous, and that is the counterbracing throughout the entire length of the span. The additional stiffness thus acquired no doubt has added much to the life and general efficiency of this kind of a bridge. The bottom chord, which consists of three or four pieces packed together, is spliced by means of oak fish plates, notched into the sides of the stick to be spliced. The splices are arranged to break joints, but one stick being spliced at a time. The proper arrangement and proportions of these splices constitute quite an interesting feature of the detail design.

Floor beams may be used, resting on the chords, or suspended, or the wood joists may run crosswise and they themselves rest on the chords, doing away with floor beams entirely. One objection to this latter construction is the chance it gives for dirt and moisture to collect along the top of the lower chord. A good specification for this, or any other wooden bridge exposed to the weather, is to omit painting until the timber has been thoroughly seasoned in actual use for six months or a year.

For several reasons this type of bridge has fallen into disuse, except in the far West. The cheapening of steel, the lesser cost of erecting steel bridges, the growing scarcity of suitable timber, and the passing of the bridge carpenter, are some of the principal

causes that have given the steel structure the preference. This transition from the type consisting almost entirely of wood to the entirely steel structure was not accomplished at a single bound, but instead, there is quite a distinct type between the two, which up until a few years ago was built quite extensively throughout the middle west, and is to-day a favorite construction for a large part of the country lying west of the Missouri river.

This intermediate type is the Pratt Truss Combination Bridge, consisting of wooden compression members and iron or steel tension members. The floor beams, which were made sometimes of wood and sometimes of iron, were usually suspended the lower chords and main ties being eye-bars or loops connected at the joints with pins. This bridge requiring less skill in carpentry to frame, and being less expensive to erect than the Howe Truss, naturally took the place of the former where timber was to be had and freight rates did not permit the use of an all-steel structure.

The King Arch, which is no arch at all, but simply a truss bridge with a curved top chord, was built quite extensively by the King Bridge Company twenty-five or thirty years ago. Every bridgeman is familiar with its general appearance, and many are acquainted with its many unique features, which have been the chief causes of its falling into disuse.

The top chord consists ordinarily of one or two I-beams laid flat and curved to the required radius. It has been said that this radius was a constant for all spans, and to make up a span of a certain length, it was only necessary to strike a chord of the given length on the beam which was already curved and in stock. A cold chisel, a sledge and a blacksmith did the rest, and the top chord was ready to be punched to receive the connections for the posts and diagonals. The posts consisted of star shapes, usually forged to a round at the top and threaded for jaumb nuts connecting it to the top chord. If the span was short, side braces were provided, also of a star section, provided with a jaumb nut connecting to a sort of a sleeve attached to the end of the *needle* beam, which was extended a foot and a half or two feet outside of the truss for that purpose.

The bottom chords were made from thin flat bars (4″x½″

was a common size) reduced to a round and threaded at the ends, the threaded ends coming at the shoes and the bars being continuous from one end of the bridge to the other. For shipment, these bars were folded on themselves once or twice and wired together, similar to bundles of hoop iron. The folds would, of course, be curves of large radii. This method of shipping in one piece is no doubt responsible for the thin bars that were used. Another condition which called for the use of wide thin lower chords was the fact that the floor load was supported on these bars, the wooden joists running crosswise of the bridge and the floor plank being laid diagonally.

It is a matter of common observation that if a bar be subjected to tension, it will support a much greater load acting as a beam than it will when no tensile stress is applied. The writer has several times tried to develop a formula for properly proportioning such bars supporting a transverse vertical load simultaneously with the direct tension in the lower chord on the assumption that the initial tension materially increased the effective depth of the bar used as a beam. It was on this hypothesis alone that I could in any way account for the bars holding together under such loading. This question was discussed freely at the structural section of this society some time ago and the general opinion was that Newton's law had been tested too often to be discarded in this case. "Each force must produce its effect independent of all other forces." We can, therefore, infer that these bridges have seldom, if ever, been loaded so that these chord bars were strained beyond their elastic limit. Such loading would be far below the ordinary assumption for country bridges at the present day.

Another feature peculiar to this type of truss is the impossibility of properly bracing them laterally in the plane of the top chord. The top chord bracing must stop off several panel lengths from each abutment in order to have sufficient head room at the portals. I have, on one or two occasions, seen make-shift attempts to remedy this defect by placing posts on top of the chords of sufficient height to give the required head room, and attaching the top struts and portals to them. This arrangement gives somewhat the appearance of the English idea of bracing the top chord

of pony trusses, which was illustrated in the "Engineerng News" a few years ago. This illustration showed a pony truss with a curved lattice strut running from the top chord of one truss to the top chord of the other truss. The curve is sufficient to allow the necessary head room underneath.

It does not take a very close study of the King Arch to infer that the foundry and smithshop constituted the greater part of the equipment of the Cleveland Company in its early history. This is also true to a greater or less extent of the shops of other bridge concerns at this time. It was a case of cutting out the bridge to suit the equipment.

One of my first mpressions of the bridge business was received just after leaving college. While crossing one of the many bridges spanning the Des Moines river, not far from my home, I was struck with the airy gracefulness of an intermediate post some thirty-five or forty feet long, consisting of four angles, about 2x2x$\frac{1}{4}$" laced four sides. Why the designer had used so little material and so much shop work would not be quite plain at first sight to one used to designing bridges under the present conditions. Mr. Bridge's history of the Carnegie Steel Company, however, explains quite forcibly why four small angles and so much lacing were used, instead of two channels laced. In fact, the matter becomes quite clear when one remembers that when angles and bars were selling around 2 or 2$\frac{1}{4}$c, the price of beams and channels was a cent or a cent and a quarter higher.

Chords 8" or 9" deep, made up of four angles and three plates is another offspring of this price differential. With the difference in price eliminated and material selling around 1.60c, built chord sections commence only when 15" channels cease to be economical. When material cost at the mill twice as much as it does now, we used to design floor beams with just sufficient depth at the ends to allow for a sufficient end connection, or to leave enough metal in the web to resist the end shear. They were tapered on the bottom from the ends down to what was considered the required depth at the center. The web was spliced at the center and the material for the two halves was ordered, either sketch, or in a rectangular plate wide enough to cut both halves without waste. I remember seeing a bridge of about a

240-ft. span on which the floor beams were made up similar to a trussed purlin on a mill building, except that the joints were pin connected. These illustrations serve to show how the bridge was designed to suit the price of material.

About that time, it was the fashion to make pin connections wherever possible. Rods with plain loops, or bent loops, ornamented the bridge at every turn. Transverse struts connected to the chord pins by means of a yoke or U shaped bent plate, making work galore for the blacksmith and machine shop. In short, the pin connected idea was carried out to the fullest extent. At top chord points, the laterals for the adjacent panels, as well as the vertical sway rods, connected to the chord pin with a bent eye, and on top of these came the yoke at the end of the top strut sometimes tapped so as to form the pin nut, and sometimes bored so as to fit the reduced end of the pin and rest against the shoulder. The use of wing plates at these points, as well as for the bottom lateral connections, was an improvement over the bent loops, but requiring, at the same time, more material and more smith and machine work. A further illustration of this idea, that everything should connect to the chord pin, is seen in the stirrup floor beam hanger. Two hangers at each end of the beam were at first used, but later it was considered better engineering to use but one and make the pins large enough to carry the load from the beam suspended at its center. While we occasionally see a hanger of this sort to-day, all up-to-date engineers prefer a rigid connection of the beam to the post, either above the chord or below. In fact, rigid connections are as conspicuous now, in most bridges, as the loose pin connected joints were formerly. The decrease in the price of steel has enabled the engineer to provide metal enough to overcome whatever secondary stresses were produced by rigid connections where the gravity lines cannot intersect at a common point. Stiff laterals are being used for the lower chords and sometimes for both chords. Counterbraces designed to take both tension and compression members are being substituted for counter rods with loop eyes and turn buckles.

The Whipple or Double Intersection Pratt Truss has been used mostly for long pin connected spans, where the height of

truss brought the tension diagonals too nearly vertical, unless the panels were made longer than desirable. The diagonals were accordingly made to extend over two panels, thus bringing their inclination more nearly 45°, and the shearing stresses were carried to the abutments through two separate systems. Dividing up the stresses in this way, by reducing the stress on the separate members of the web system, produced small slender diagonals which would vibrate excessively under passing loads.

A saving of material was effected by connecting the diagonals to the intermediate posts, which crossed them at the center, thus dividing by two, the $\frac{L}{R}$ of the post. For present price of material and shop conditions, there is no doubt but that the decrease in weight thus attained would be more than balanced by the increased cost of boring the extra pin holes, making the extra pins and forging the additional heads on the bars. Reducing the $\frac{L}{R}$ of long vertical posts is so much more effectively accomplished at present on our long sub-divided trusses by the use of the horizontal struts, rigidly attached to the center of the posts, that the use of the Whipple truss to-day would be going a long way around to produce a poor and expensive piece of engineering. Any one who has had the pleasure of resurrecting an old span of this type from the bed of a river, and, without the aid of either strain sheet, or working drawings, making it over again into the semblance of a new bridge with a brand new coat of paint, should certainly feel grateful that some "old things do pass away."

The Warren Truss, with all its web members, both tension and compression inclined at an angle, has found its most legitimate use in riveted construction. The difficulty in securing a satisfactory connection of the floor beam to the trusses, other than by suspending them by stirrup hangers, is the principal objection to their use in pin connected work. The extra metal required in the intermediate posts, because they are longer than a vertical post, and on account of reversal of stresses near the center of the span, would probably about balance the material and extra shop work on counter rods which are not required by the Warren bracing.

The Pratt Truss brings us right up to date in the evolutions of bridge construction. For simplicity, minimum number of parts,

duplication and economy in shop work, it has no equal. Pony trusses up to about 90′ and through trusses from 80′ to 180′ spans are built after this type in both pin connected and riveted construction. For spans above this length, the Baltimore or sub-divided Pratt truss was used for a time, but gave place to the Petit truss with curved top chords, but with sub-divided panels as before. Two different methods for carrying the sub, or intermediate, panel loads to the panel points proper have been in use. The first was by the introduction of the sub-strut running from the intermediate point, from which the load is suspended, down to the foot of the post toward the end of the span. The other and more recent method is by the introduction of the counter running to the top of the post toward the center of the span.

A pleasing effect and duplication of drawings and shop work are produced on long spans by making the height of truss at the various panel points such that the angle of deflection of the top chord at the joints is constant from the center of the span to the hip. This produces a curve flatter than either the circle or parabola.

The tendency at the present time is in the direction of riveted construction for both pony and high truss spans of moderate lengths, while for short spans up to about 35′, the simple I-beam span is a decided favorite. It usually consists of either plain or punched beam stringers spaced from 2 to 3′ apart, provided with a simple lattice railing on either side. These stringers rest upon some sort of a steel wall plate at the abutment to which they are either bolted or clipped. In case they are clipped to the wall plate the joists can be shipped entirely plain, thus saving the extra cost of handling and punching them at the bridge shop. In fact the uses of the clip in the lighter kinds of steel construction are increasing every day.

Twelve or fifteen years ago it was a rare exception to find a riveted bridge, either pony or through truss, spanning a country stream. Now, however, in the states of New York, Pennsylvania and Ohio, and I understand parts of New England, it is almost the exception that pony pin spans are to be found, and quite a respectable percentage of through riveted trusses are making their appearance. For the country outside of the states mentioned

above, the pin connected trusses for the ordinary run of work have undisputed sway.

In the older and wealthier sections of the country, where the traffic is such as to require the best type of bridge, as well as correspondingly good roads, the plate girder is of course being used extensively; and solid floors of one type or another are not at all uncommon, even for country locations. Plate girders weigh more and are more expensive to haul and erect than truss spans, and their use is consequently limited as stated before to sections where the price is a secondary consideration to securing a permanent and substantial improvement.

DISCUSSION.

PRESIDENT—The subject is open for discussion.

MR. LYONS—I am not very much on Highway Bridges, Mr. President; my experience has been more in the Railway line. We build them. The main feature referred to in the paper about changing from the pin-connected to the riveted trusses he didn't bring out, possibly, as emphatically as it has taken place. The tendency is now for all the pony trusses to be made of the riveted or bolted type, that is to do away with the pins and bars, and ship them in as large sections as can be hauled to the bridge site. That is really the governing feature in determining the sizes of the pieces that are shipped, and for the larger spans all the members can be shipped separately and then assembled at the site. The stringers are mostly of steel now in place of wood. This has taken place in the last four or five years. It used to be wooden joists laid over the floor beams; now they have steel floor beams, steel stringers and on the stringers they will place a nailing strip on which the floor is laid and nailed. This is certainly a vital change over the previous practice, and another thing that has helped them out in that line is the rolling mills do not roll the sections with the webs so thin that they are translucent. On the heavier classes of highway bridge work the buckel-plate floor with the paving is used, and we have as good an example as any right here on the Sixth Street Bridge, Pittsburgh. That is probably as fine an example of heavy highway construction as you will find. The expansion there is probably as interesting as any bridge

you will find, too, if it is studied out carefully and see the movement. I think if you would go down under the north end of that bridge and make a study of it there you might observe the result of the expansion. It is pretty hard to get a pavement of that length and not have the asphalt crack. That is really the difficulty in connection with it, although the approaches that are made with expansion joints, in a way, are not entirely satisfactory, but the only method to overcome that is to make the asphalt complete on each span and then have the apron plate that reaches over the spaces and allow this apron plate to slide back and forth on the asphalt, which will necessarily make a little drop there. You cannot very well make an even surface.

MR. WHITED—Speaking of what Mr. Lyons says of the increasing use of steel stringers, the two principal reasons for that are that the timber is getting dearer, and at the time of using wooden stringers steel I-beams and channels were worth 3 1/10c per pound. A while ago they were sold for less than a cent; now they are 1 6/10c. Speaking of asphalt paving, I think the bridgemen are not always very familiar with the nature of asphalt paving. The rock asphalt will crack no matter how particular you are in putting it on, but that does not injure its durability. It only gives a little chance for water to soak through it. Asphalt is a peculiar substance and it is a difficult matter to make just the right mixture of it. If it is a little too soft it softens in hot weather, and if it is a little too hard it cracks in cold weather. It is almost impossible, without wide and long experience, to get the right mixture of it so it will stand.

MR. FLANAGAN—Mr. Canady did not make any reference to suspension bridges on highways, although his paper goes back to a time when there were still a good many of them in existence with comparatively small span. It appears as though they were going to be restricted to the very long span, as near as I can judge the present tendency. But most of us remember the old Smithfield Street Bridge. I remember it because I had to cross over it while the new one was being built. I remember the old sign that was up on it at each end of the portals restricting the number of head of cattle that went onto the bridge at one time, vehicles to drive no faster than a walk and processions to approach without

music. The people that had to use the bridge heaved a sigh of relief when the present bridge was put there and no signs or directions on it. I suppose that was a feeling of rejoicing almost equal to what it would be by abolishing the tolls on our bridges.

MR. CANADY—I didn't say anything about suspension bridges because I was afraid I might hurt the feelings of some bridge contracting agents for steel bridges. That was the bane of the bridge contractors in the West, the wire suspension bridges. He would go around with a wire bridge without any sort of stiffening at all, any pretense at stiffening the bridge. The wire was made up on the ground and the cables, if you might call them cables. I remember of looking at a specimen, about 150′ span. They were just simply wires met together and a sort of pretense made of twisting them, but didn't amount to more than to bring all the strains on a few stands, and these wires were ordinarily anchored on the bank to any old log, and when the spring floods came and the ground got good and moist, the bridge began to have a tendency to go down, and the people crossing those bridges after they got in that condition had to be sure they crossed early in the evening, before they got very much of a "load" on. They would think sure they were just hitting the high place, the way the bridge went up and down.

MR. LYONS—In referring to highway bridges of the suspension type, if I am not mistaken, they got a black eye from an accident at Wheeling. The bridge was built without any wind bracing, and it got to vibrating from a heavy wind-storm so that the cable slipped off the saddle and the bridge went down.

In the last six years the plate capacity and the tonnage output has increased very materially on the shapes. The angle tonnage is probably very much greater now than it ever was, as far as the percentage in output is concerned, and the percentage of the Z-bar columns used in building construction is very much less than it was six years ago; so that there is a changed condition all the time that the designer has to meet.

MR. WHITED—Before we adjourn I move that a vote of thanks be tendered Mr. Canady for his paper. Carried.

MR. FLANAGAN—I move that we adjourn. Carried.

CHARLES W. RIDINGER, *Secretary.*

CHEMICAL SECTION.

A joint meeting of the Pittsburgh Section of the American Chemical Society and the Chemical Section of the Engineers' Society of Western Pennsylvania was held Thursday evening, May 19th, 1904, at 8:20 P. M., in the Assembly Room of the Engineers' Society's House, at No. 410 Penn Avenue, Pittsburgh, Pa.; Mr. H. E. Walters presiding as Chairman, and twenty-six members and visitors present.

The regular Secretary being absent, Mr. Woods was asked to serve, and the minutes of the preceding meeting were read by him and approved.

CHAIRMAN—The next business is the report of the Committees. Any new business? We are ready for the address of Prof. Chidlow on "The Status of the Chemical Technology of Bread-Making."

PROF. CHIDLOW—Mr. President and Gentlemen: I did not have any time to prepare anything of a special nature, as I should like to have done, and I intimated to Mr. Walters that it would be rather in the nature of a talk upon the status of the chemical technology of bread-making. There is so little known of it, and a talk upon it would only be an introduction. I dare say many of you will be surprised to learn that there is such a thing as chemical technology of bread-making. It is a remarkable fact, however, that, seeing that bread-making is something over 4,000 years old and that the variations connected with its production are probably older than in any other industry are of the most complex character—exceedingly so. There is not only the problem of physiological chemistry in the matter of the flours themselves and their variations, but there is the further problem brought about by bacteriological conditions, which are never under control and to a large extent are uncontrollable, and until within the last three years there has been no attempt to even control the temperature. Up to about 1884 there was no attempt made, in a systematic way, to get at the facts underlying the chemistry of bread-making. William Jago, of Brightling, at-

tempted at that time, or just immediately preceding that time, to formulate the chemistry of the immediate changes taking place in bread-making, but I presume they were so profound that he carried on the work to a point that he thought was sufficient for one man and dropped it there. So far as I am aware, he has never done anything further.

A number of associations, some of them in Germany, one in Vienna, two in Cleveland, four or five in England, have acted independently towards systematizing the methods of bread-making, and in Germany, to some extent, I think in Crondstadt, they have taken up something of the chemistry of baking by simply making small baking tests. But there has been nothing done of a systematic character outside of the United States, except this effort that I speak of by Mr. Jago, ending somewhere about 1886, although the work of inquiry has been going on constantly, but has only been going on in the same direction that the bakers themselves carry it on. They have not attempted to solve the problems of bread-making by the researches into what takes place, nor into the chemistry of the constituents, nor into what constituted the chemistry of the flours or wheats, and it is something of that nature and of its practical application in the bakeries under the control of the Ward-Mackey Company here that I wish to speak to you of, because this is the initial effort in the history of baking in which chemistry has been applied in a practical way.

Since 1889 I have been applying chemistry to milling and to the problems of baking generally in a commercial way, and in 1895 I associated myself with the Pillsbury-Washburn Flour Milling Company, of Minneapolis. I had met Mr. Pillsbury very often and had discussed a number of the practical sides of milling and the probable profits of the application of chemistry to milling. There are a good many products in milling that are going to waste that are valuable products, and I had taken up the discussion of these several times, which ended in 1895 with my taking the matter up with Mr. Pillsbury and my going with them for something like three years. The problems of milling are somewhat peculiar in character, involving questions that the millers themselves are not conversant with. Mr. Pillsbury said to me in 1894: "Mr. Chidlow, if what you say is true, if it is a good

thing for us millers to have chemistry in the mill, why we ought to get it. We don't know it though. We don't know what we want, and we don't know whether it would be any good for us." And that is true to-day. Although there is quite a large number of mills in this country now, some probable fifteen, employing chemists, they are still in that position. They don't know what they want; they think they ought to have it, but the majority of them are spending the money groping for some information. So you see the millers' position is pretty difficult. The chemists' work is in a worse plight. The chemist in a mill may ask: "Well, what do you want me to find out? Is it any good for you to find the starch or the fibre in wheat?" "Well, I don't know what all we should find out. What do we want to know?" "Well, I don't know what you want to know." And the miller don't know. The real problems of milling, so far as I have found the commercial side of milling, are those of getting the largest amount of a certain grade of merchantable flour from a given amount of wheat. He believes—taking a miller from a certain section, taking either the Oklahoma miller, or the miller that is milling wheat grown in the South-Central States, or those taking it grown in the Northwest,—that to make a certain type of flour requires a certain wheat, and these wheats have a certain mixture, so much of gluten, and a certain color, the color of which is determined by grading carried on from crop to crop. As a matter of fact, while the constitution of the grain varies widely, the percentage of ash will vary widely,—vary from 1.6 to 2.3%, and the amount of gluten will vary from 11% to 16% in the wheat and occasionally in the flour—it is patent flour, that is standard grade, usually known as "Pillsbury's Best," and "Washburn Gold Medal," etc.—those are standard patent flours having a pretty constant constitution. The ashes are pretty constant—under my observation since 1893 having averaged .45 ash, and .46 would be high, and .39 would be very low, so that there is an average composition of the flour in some respects. But if a housewife took the flour, say of one year, and was able to make good bread of it under conditions, if she took so much yeast which would have a certain standard strength or activity, so much of each article, and put them together in a certain way, and left them

for so long at a given temperature, and she did that next year on the same plan, she probably could not get good bread. It would vary quite a little, and in fact usually on every crop the millers have trouble. The crops run into each other. They get their wheat about September or October and begin to grind 5% and increase it to 10% in two weeks and increase it to 20% in another two weeks, and by the middle of December they are supposed to be running new wheat. In 1898 there were complaints all over the country from housekeepers, "What is the matter with the flours?" That was chiefly the complaint that was affecting the northwestern millers. And the matter was that there was simply a larger amount of gluten. And that amount that it required a long time to ferment in the dough. It would require pretty nearly a third of the time longer. The miller does not know that, but he hears these complaints, and he, knowing that something is the matter, takes a type of wheat that will have more gluten, that is "hardened" wheat, as he terms it, and he finds the complaints grow less, and he uses softer wheat until he reaches a point where the complaints cease. Now that is practically the miller's position, and considering all the interests involved in milling I am surprised that someone has not taken up that field in addition to the few in it already. We need baking and there is an unusual demand for it, the only difficulty being its application; and it takes time to get into the facts—like some of my friends in the mills out there in Minneapolis. They ask: "Mr. Chidlow, what do you look for when you go into the mill? What do you want to find out?" Perhaps a little survey of the actual milling principle would not be out of place. Taking the Pillsbury mill, you will find they are milling about 12,000 barrels a day, using an average of five bushels of wheat to the barrel, so that is 60,000 bushels, and you can imagine that to use that every day for one mill when they have five mills much smaller than that, and there are other concerns with five and six mills, and that is only half the manipulation, the Pillsbury Company alone using something like 130,000 barrels per day. That involves a serious problem in the supply of wheat without disturbing the market, so that they have to draw the wheat from all sections. The Northwestern mills have denied using anything but Spring wheat, and down in Oklahoma

I see telegraphic orders being received from various firms that I knew well to be shippers for all the wheat they had on hand, and those orders were going into Oklahoma and all the other States around there, the Northwestern mills being competitors with the mills down in that direction; and if you knew the kinds of wheat and the kinds of flour produced in the different wheats, you would conclude the Northwestern mills could not use that kind of wheat. But they are compelled to go abroad to get supplies in this way, and that means that they have got a mixture going into their rolls of some very hard grades of wheats that are difficult to break up and others again so soft that when they receive the impact of the corrugated rolls which are muffled for first breaking the berry, they simply flatten right out and break up largely into flour, while the harder berries resist. Well that is one of the problems the miller has to contend with, and he does not know how to battle with it in a practical way. He would know if he knew something of the nature of the berry he was battling with. The hardest wheat to reduce is that of the flour that shows the highest percentage of ash, and the berry increases in its proportion of ash, that is the young sperm of the berry increases in proportion of ash, from the crease of the berry outward to the bram, so that in putting the wheat on the rolls the millers first attempt to reduce it by cracking it loosely, then to put it over smaller rolls with the wire differential to again break the bram—to loosen the whole thing rather, so that when it is brought over smooth rolls it will be reduced into flour. These granules of various sizes are sorted and separated to carry out all impurities and then go over these smooth rolls. The first flour to be reduced is that near the crease, and also the flour from the softer wheats, the wheats that they would draw from Iowa and Arkansas and Nebraska, and the harder wheats and the harder parts of the soft wheats would resist reduction until some of the later rolls. That would entail loss to the miller because most of the flours that he draws from the wheat in the first rolls or breaks he spreads as test rather in the crease of the berry, and that is usually run to low grades, to dark flour. The latter part of the wheat is known as "sifted tailings." They are so hard to reduce that in the mill they get that name. These sifted tailings become mixed with particles of bran

and in the reduction of the larger granules of the young of the sperm together break, but they are the parts of the flour that have the highest proportion of gluten and the highest ash, and while I was with the Pillsbury Company there for two years or more we had these wheats to deal with, and the smoothed wheats were the best wheats to deal with. The finest grades of wheat had it, and the only way we could get rid of that was to wash it, and it was a serious problem to wash and dry that wheat, dealing with that large amount, and we could not very well separate the soft wheats from the hard, so that the soft wheats became soaked with water while the hard wheats had just commenced, and the time required to dry the soft wheats would render the hard wheats so brittle that they would have to be wet over again; so that the miller, to get over that, simply took the hard wheat off and lost all the flour from the soft wheats.

And it was to attack some of these problems that I centered my attention with the Pillsbury Company, which we did fairly successfully. Well, now, all my experiments with the mills, even to-day, are along such lines. They are problems that have to do with the different conditions and different milling systems over here. As an instance, in 1890 we received a sample of flour and wheat from the Breer Milling Company, Seymour, Ind. I was well acquainted with Mr. Seymour, and he said in his letter: "I send you by express sample of new wheat and of the flour that they mill from it. We shipped a lot of this flour out a few days ago and it has been returned to us as being unfit for bread." Well, I sent it to the laboratory and at the same time gave instructions to make it into bread, and we got our bread sample and the loaf was very white and a very close loaf. Those of you who have lived in the South-southwest, Tennessee, Carolina, Texas, will remember some of the bread you get down there, a close, white, small loaf, but very sweet. But this was a very dark loaf, darker than any kind of flour that they could make in the Northwest, and before we got the laboratory results I had ordered two or three series of bakings, one involving the use of lactic acid. I suspected, without having any real basis for it except the knowledge that the weather preceding the harvest had been very dry, that the ash was very high, and possibly that there is the free phosphoric acid

in the berry, which under normal conditions would be washed out by the rains, and by the time we got our chemical data we found that the use of our lactic acid had remedied some of the difficulty, that the bread had achieved its normal color and whiteness and lost some of its unpleasant flavor and was a little larger, and at the same time our chemical data showed that the ash was unusully high; those flours from that district, patent flours, run at about from 33 to 35% ash—this one was about 45%, and then it was reported that this increase of ash was largely free of citric acid. There was only one way to get that out. It would be useless to deal with the flours. The wheat all through Central Indiana, parts of Ohio, all through Illinois and north, all through Missouri, was all the same character. We could deal with the problem from the consumers' point of view by telling them what to do, but I thought that would be all sorts of trouble, and I told Mr. Plass that they would have to soak that wheat sufficiently long so that the water would penetrate to the centre of the berry and then dry up, and the water, of course, would take out the soluble salts. Mr. Seymour said they had been milling down there forty-seven years and never had to wash their wheats and never met with that difficulty. They would never wash those wheats in any of the soft wheat districts. They have had to wash them often in the hard wheat districts, chiefly because of the chaff. I had some experience in washing wheats in India. They are so careless with milling, and the natives are anxious to put a few pounds of granules of mud in with their wheat to sell as wheat, so that much of the wheat had to be washed there; and we had a very similar problem to deal with in India some twenty-two years ago. So Mr. Plass at first refused to carry out that plan. He said it involved so much trouble and expense. It involved the erection of tanks and bins to store their wheat, taking at least eighty hours, and he finally came up to us and we treated some of the wheat that way and ground some of it into flour and then he tested it; that, though, was the only perfect flour, and I believe most of the mills followed his example for that year. I never met a problem like that before. There are problems every year, though, often down in that very grade, problems every year that vary and in many cases are dealt with by the miller in a more or less uncertain fash-

ion; that is, he will experiment, and finds by milling this way he decreases, and milling another way he increases his difficulty, and finally reaches a medium of results which he adheres to. But most of them will lose in the milling.

Another instance of the way that these things occur in the mill came under my notice in Kansas. I went through all the hard wheat districts in September and October of last year to determine the nature of the crop, to advise our firm as to buying. I came to a mill in South-central Kansas milling extremely good flour, and in going through the mill with the proprietor I took some of the orfuls bran in my hand. I said, "Are you milling in your usual way?" He said, "Yes; is there anything unusual about this bran?" I said, "Why, it seems to me you have a great deal of flour on there." "Well," he said, "we are milling just the same as usual." I took a sample of the bran, and when I reached Pittsburg I made a determination of the amount of flour deducted to the bran there, which was 32% of the bran; 32% of the use of the bran was flour. The average flour on average bran, when I was in Minneapolis, was about 15%, and I instituted methods for the Pillsbury Company which brought that down to about 5%, and I think that is about what most of the Northwestern mills now run. Now this mill had 32% of flour on its bran, that is on the coarse flake bran, and then on the fine bran there is still more flour escapes, so that they were probably losing 20% of the weight of the bran, or 20% or 30% of flour by that method of milling. When I communicated that to the man and figured it out as to the amount, he came up to Pittsburg and wanted to know where he could get a man that would go down and check up their results. It is only in cases like that that the miller is able to find out just where he can make use of chemistry in milling, but the problem of the miller is a very small one compared with that of the baker. Every variation in flour brings about a variation in the bread. In order to produce a loaf of bread, using so much yeast, temperature and flour for each loaf, if we take a range of flours that are milled this side of the Rockies they would range from about 60% of the mean amount—the mean being the standard Northwestern flours, "Pillsbury," "Gold Medal," etc., ranging from about 63 to 65% and up to 130%; that is, if we should have to use either that per-

centage of time or that percentage of yeast, as compared with the normal amount. The average amount of yeast used is about two pounds per barrel for a fomented period of six hours. If we were working with a flour of normal character we would use, then, six hours and two pounds of yeast to the barrel. If we had a flour that required 20% more fermentation we should have to use either 20% more yeast or 20% more time. It would throw all our work out of harmony with the general run of the factory, and if we used that much more yeast it is that much more cost to us. But suppose we did not know that we had to use that, our difficulty would be still greater; we would not know what was the matter with the bread. Well, there is not only this difficulty with the flour, but fats. All bakers now use fats of some kind,—lard, butter, cotton-seed oil, coacoanut oil, a number of other mixtures, beef fats; cottolene is used to some extent, but every one of these fats affect flours differently. If lard is used with the average flours under usual normal conditions, about 20% of it is broken up into fatty acid and glycerine. That will break up the load, which is large, closer, finer in texture, and allows the loaf to spring up much more. Another shortening oil, such as cotton-seed oil and coacoanut oil, with standard flours, would not break up at all. We would be able to recover all of the fat as fat and not as the fatty acid, and in that case fermentation is considerably delayed; the mixture of the dough, as compared with other doughs, standard doughs, would be delayed perhaps from 30 to 50%, and the loaf is very much smaller, the texture is coarse, the loaf is dark, it dries out rapidly on account of the coarseness, and one feature of it is that as the loaf dries out it brings the fat to the surface, so that rubbing your hand over the crust it becomes equally greasy. Yet these fats are good for some other flours that just want that kind of treatment. For milks again, the normal old milk nearly always reduces the size of the loaf as compared with the loaf made with water. It reduces the size, it makes the loaf dry out quickly after it is baked, it keeps it impure, as compared with a certain standard, and yet again there are some flours that the milk has an entirely different effect upon, and the milk often, a very small amount, will establish a flavor rapidly, whereas a large amount in the same kind of flour will cause a cheesy effect.

unpleasant and destroying the good flavor of the flour. The problems throughout are exceedingly complex. I had occasion to talk with Dr. Wile some little time ago regarding the introduction of the macaroni wheats and I advised him to put one of their men upon the chemistry of flours, macaroni flours especially, with a view to determining the methods by which they should be used outside of their use for macaroni and also to determine the chemistry of macaroni manufacturing processes, because they are complex, too. We had some experience with them in Washington this time last year. We found that if we made a dough with macaroni, just with water, stiff dough which is used for making macaroni, that if we worked the dough very much it became very short. If we worked it a little, just sufficiently to mix it well, it was exceedingly tough and resisted being drawn, the bread containing about 16% of gluten. If the dough was worked very much it became very short and broke with very little effort, but worked still more it became tough and elastic and a piece of dough as large as the hand could be drawn out to the other end of the room there without breaking. A number of complex changes must take place in just the mixing of the dough, no alteration in the temperature, simply an alteration apparently of the amount of air included. In the Ward-Mackey Bakery and the Wrad-Colley Plants in St. Paul we employ a special mixer for incorporating air into dough. We blow air while the doughs are being mixed with a view of giving them an excess of oxygen. If we carry out that process under our conditions long, the mixing and the blowing of air into the mixer, for say twenty-five minutes, we achieve maximum elasticity in the dough. If we carry it on for thirty minutes the dough becomes quite soft, and if we run it for say forty-five minutes it becomes soft, elastic and cohesive, and more like a dough that would be made with starch and soft dough. While if that dough is mixed, for say, twenty-five minutes, it is stiff, and if cut with a knife would stand solid or a straight wall for ten minutes, but by continuing the beating, the dough becomes quite soft and mushy in character. From that you can easily imagine that the changes that take place there are unusual, and we don't know yet what it is that takes place there. Last year I had a special sample made and passed through carbon-dioxide; we found that those changes

took place, just as in the presence of oxygen gas, but that they took place slower. We collected some of the gases that came from the mixture to see if there was any change in them, but we could not discern any in them; I guess we did not go sufficiently far. We used nitrogen in them and found that our changes went on just as before, except that they took still longer time. We used lower oxygen and found that our maximum stiffness took about three minutes. The dough broke down very rapidly, so from that tendency I inferred that it is a character of exstation and probable hydration. This change, however, is not at all uniform. It will vary with every flour that we use that varies from a given standard. That standard is really the amount of dry gluten, and would be, say, about 12%, and where the proportion of the gluten would be somewhere about 65% dry gluten and the flours 35% gluten—all flours vary, even the gluten rather varies in the constituent amount of gluten and glutanic it contains; it varies in the time that this achieves maximum stiffness as a dough, and this again varies apparently with the proportion of ash. That is, if we get 66% gluten in a flour having .45 ash, and take another flour with the same proportion of gluten, with a little higher ash, this maximum stiffness will approach 30%. That is, it will take about fifteen minutes to bring it about. Now we have an easy way of adding the ash to the flours, because they are what I have said about milk, which affects doughs variably. That is, the gluten seems to take up the ash of the milk in some way, because we can't separate that ash except by chemical methods. It combines with one of the constituents of gluten, gliodine, and forms a compound; then as it approaches maturity, the aromatic acid being formed, which gradually combines with the ash separated from the milk, so that the gliodine, that is the gliodines that are combined with the ash of milk, becomes gliodine again; that is, it changes into glutanic with the condition of the milk, and changes back into its original form upon the formation of the normal acids of the dough. All these are inconstant. They are never the same. The acid product of the dough is never constant. Some times the proportion of lactic acid may be 90 to 95%, but other times it will reach from 60 up to 95%. So that these acids have the mastery of the dough at a different ratio. The lactic acid effects the dough

badly, and altogether dough affects the acid badly sometimes. Out of about half of 1% calculated in the dough, the total acid, probably 75%, is taken up by the gluten to form gliodine and making the dough elastic and giving it that stiffness so that it will spring in the oven under the expansion of the expanding gases. So far, I believe, the Ward-Mackey and the Ward-Colley Bakeries have been the only ones in the world to put some of these applications to commercial test, although some of my old pupils have taken up the general question of the technology of flours for work in the laboratory that might determine some of the immediate properties of the flours that they are buying and using, but they have never gone far enough into it, never cared to put in the time to attack the problems of their bakery from the chemical standpoint. They have dealt with it rather as a technical point, have preferred to leave the chemical side to someone else who has more time. So that if any question came up involving more research, then they had the knowledge to carry it out, but usually they turn it over to me or to someone who is working with me.

I dare say from what I have said you can, to some extent, measure the difficulty I have in putting these questions before you, unless I attack one of them, seeing that there has been so little done upon the chemistry of bread-making outside that connected with fermentation. One of the most interesting problems we have had to deal with this year is brought so close to the question that has been interesting our geologists for a number of years. In determining the formation of the acids one of the first questions that we have met with was in going through the regular analysis of breads and doughs, the gradual decrease of fat. That question has been taken up by Dr. Woods, of the Maine Experimenting Station, and also by Vorace, of New Jersey, and I think Harry Snyder, of Minnesota, and they had all experienced this difficulty of accounting for the loss of fat, but they lightened the question to some extent by assuming that it was a glutoff. In going over the proportion of the acids found we found some that we could not account for, and in making our determinations for the fat we found we usually lost, and it occurred to me that the additional acid that we could not account for could be sought for in the loss of the fat; so we determined the glycerine in the flour and in the

doughs of those that fermentation had been going on in, and found that under certain conditions, where the formation of lactic acid was prevented to some extent by using a higher conductor for the doughs, that the conductor was more favorable to the yeast than to lactic acid bacteria. We found that a yeast desiring the acid, if same was taking the effect, broke it up to get the fatty acids. Just how the yeast does come to make use of that I don't know, because if we put these same acids to a dough we prevent fermentation going on. If we put the amount of fatty acid to the dough that we find broken, as decomposed fat, we prevent fermentation; that is especially true of bacteria acid. If we put about 65% bacteria acid we stop fermentation entirely, and yet if we put butter in bread we find four times that amount of bacteria acid present. And so it occurred to me, then, that probably this fatty acid was taken up by some constituent of the dough, which in turn released some other acid, which was used by the yeast for functioning. As a part of that work, which we are going on with just now, we found that—probably you are acquainted with the work performed by Mr. Taylor in Arkansas, in which he showed the disposition of nitrogen in the growing crop. The nitrogen in the proteid form was, of course, largely gluten, consisting of gliodine and glutanic. In the flours, normally they existed in the wheats that he was dealing with; they existed in the proportion of about 75 gliodine and 25 glutanic. In the beginning of the formation of the berry, the proportion of glutanic is extremely high, that is, it runs up to about 90% of the total nitrogen. As the maturity of the berry is approached the percentage of gliodine rises rapidly until the proportions change places, so that where at the beginning of the formation of the berry the proportion of gliodine is very low, at the end of the growing season the proportion of gliodine is very high. If we add acid to doughs, make a dough with water, adding acid to it neutralizes it and makes an alcoholic solution in which the proportion of gliodine has increased. If we add acid to the dough and ferment it, we find that stimulates maturity, that is that the same condition is produced as though we had fermented it longer. And one of the most surprising results achieved in these tests was that while the regular acid is baked from say, 11 to 12/100ths per cent., if we

added 12/100ths per cent. of lactic acid and fermented that the same time our loaf was lower than the acid normally in the loaf, that is, we should have an acid equal to 24/100ths, that is the acid formed under normal formation was less than the 12/100ths that we added; but we found that when we added these acids equal to that which was formed, the acid of the loaf was lower than any we did put in. We got from 10/100ths to 11/100ths, but we had as a result a loaf that was fermented much beyond the usual stage, and that would mean that we had practically matured the loaf by the formation of gliodine at the expense of glutanic, and following the doughs through, we find that they took place with those that our proportion of gliodine was increased by adding several proportions of acid. It would appear then from the whole series that we undertook, and considering them in the light of Mr. Taylor's experiments on wheat, and the light of some other works outlined by Dr. Woods, Washington, in charge of the Bureau of Plant Physiology, that the formation of gliodine is practically an acid formation, an acid albumenate, where the glutanic of the gluten is either an alkoline or a neutral alkoline albumenate, because it is quite easy for us to change them from either in a dough or by the addition of acids as I have stated; but if we would bring in these conditions milk, where we have not frequently used it, these changes would take place, or they do not take place anyway until the ash of the milk has been combined as a lactate, or some other form as an acidic salt of the acids formed in the dough. There is still a further problem. As a part of the work which we wish to carry out in conjunction with the Department of Agriculture, they asked us to use some of the macaroni wheat flours in order to create a demand for them. They wanted to stimulate the growth of these wheats because the added lands in the Western Dakotas, Nebraska and Kansas could produce from twenty to twenty-five bushels of this macaroni wheat and could only produce from five to seven bushels of the other wheats, and that meant a whole lot to them, but the millers complained against it because it was a very hard berry and the bakers could not use it, and so the Department asked us to see whether we could not use it, and if we used it in sufficient amounts they would send down a man and get out a bulletin on it. Well, we got five and ten bushel lots from

all the mills milling it in the various sections and found that the same complex difficulty came up that I have before referred to in this ash question. Under the usual conditions those flours would mature in a little longer time, perhaps 10% longer time, than our normal Northwestern flours, but under the conditions that we were making them and using ample refined cotton-seed oil, we found that they gave us less difficulty and that we could not use them at all any other way. It was not simply a question of using more yeast, it was rather a question of time, and a very long time. We are manufacturing down in the Ward-Mackey Bakeries seventy-two doughs daily, of about 800 pounds of flour in each, and there is a very large room that these doughs are in, and taking ordinarily busy days we require all of our tanks and pretty nearly all the room. On Fridays we require all of it. We only run those doughs six hours. If we use those macaroni wheat flours, it would compel us to carry those doughs for ten hours anyway. We found that if we used more yeast the doughs would still remain tough, that is, there had to be formed the amount of acid necessary to overcome something like 56/100% ash, where we had been usually dealing with 45/100. And we had to overcome this amount of ash, and it also combined so slowly that it would not take it up as fast as it was formed. We had to allow fermentation to go on at the slow rate in order to bring about this one position of the ash combined with the gluten; so that so far as this past season is concerned we have had to give up using it altogther, although I think that if next year there is a considerable amount of it grown we will see if we can't use acids on it direct.

In outlining some of these difficulties and problems in connection with bread-making and milling, I do not want you to understand that this kind of work is being done everywhere. Up until 1895 and 1896 a large bakery was impossible except to the extent that a man could get personal supervision over the entire business. To-day men who simply manage, but in most shops are supposed to be the technical men as well, are getting from $50 to $60 per week, and they are sought for as gold mines, at that. They have no knowledge—I am perfectly safe in stating that 95% of the foremen of all the bake-shops of this country do not know there is such a thing as gluten in the flours, and if you spoke to

them about starch flours they would not understand it, and you know. I suppose, from your own reading that there is a good deal of ignorance in many cases, about the mixture of it or even the composition of flours. Some years ago I had the question up with Dr. Wiley regarding some of the sugars in German wheat, and it came about in the course of his discussion with me that he thought the average amount of sugar in Northwestern flours ran about 1½%. Well, the time I was in the manufactures I never tested a sample of wheat that contained less than 4%. And he said, "Well, now you send us some of the wheat out." So we sent it, and he said, "Well, that is all we find, 1½ to 1¾%." "Well," I said, "It is my place and I have not the time and probably not the ability to go into the question of sugars, but I know there is that much sugar present, because even if we wash it out we get a certain exception for it, and if we put this extract of flour we get another expansion equal to it, and we know by other means that there is 4% of sugar." Well, since then he has told me that they have found 3½ to 4%, and I guess you know, from the text-books, that many of them refer to the reduction of starch and formation of sugars from the sugars into alcohol and carbo-dioxide. Well, in my experience with the present yeast I do not think there is a grain of starch touched in fermentation. The moment the sugar is used the dough is packed under and won't rise again unless it lies so long that bacteria will then begin to act upon the starch long after the sugar is consumed with the bacterial action of the starch, a reduction in the texture, and to some extent the texture in the sugar takes place. One of our students—we have some students there in the laboratory with us—made a determination of the amount of sugar required to ferment the doughs recently. He took sixteen doughs and determined the volume of CO_2 formed up to the time the doughs reached the punch, and it came up to 9¼ pounds of sugar for 14 bushels of ash in CO_2. Then we would require at least two pounds more to give the gas for the other operation; that is the time it went out to the punch, etc., so that there is not less than 10 pounds of sugar for that amount; that would be about 2½ pounds to the bushel used for a proportion of the dough. Of course part of that is used, probably 1½ pounds, for the formation of acid, lactic acid chiefly. So the current views

upon the changes in the dough are not at all clear nor in accordance with the facts at all. Probably in some of the very old processes, when bakeries used to make their own yeast, which was largely a mixture of bacteria, chiefly lactic acid, completed by fedoric (?) acid, comprising bacteria and amillo bacteria, but when they formed that way most of the fermentation from the starch took place as a result of the minor fermentation, not of the true alcoholic fermentation at all. It was rather—well, what would be considered now a deceased fermentation. It would not give normal bread.

I am wandering over a big field, and I do not know that I am wise. I think I have said just enough to show that there are some difficulties and about where we are at. I should liked to have presented the matter in a more definite form, but I am pretty crowded for time, and when Mr. Maury asked me to take up the question I hesitated, because I found that I could not possibly get the time and I am crowded for all we can get in down there. I have my own duties in connection with the bakeries, and I am filled in with a good deal of outside work and am carrying on some special researches. And I have to control those bakeries 1,000 miles away, and it complicates our work considerably because we are arranging our dough for a given percentage of milk, and if they bring water in it it means that our doughs are going to be gotten ready earlier than we have designed. We have kept up a pretty high record, a better record outside of Pittsburg than we have inside. I don't know that I care to go on any further unless you want me to answer some questions. I am very much obliged for your attention.

CHAIRMAN—Gentlemen: You have listened to the very interesting address of Mr. Chidlow and, as he said, he is ready to answer any questions. The subject is open for discussion. Mr. Stahl, have you anything to say?

DR. STAHL—I would like to ask whether the bread-makers have as much trouble with their yeast as the brewers sometimes are said to have?

PROF. CHIDLOW—Well, yes; they have quite a good deal of trouble, but I don't think it affects the baker to the same degree. Of course we test the yeast every day, but we test it chiefly for

its strength. It varies in gas production from about 83% of the standard to about 125%. That means that we have to arrange the amount used each day.

DR. STAHL—That is you simply test it with sugar.

PROF. CHIDLOW—Well, we test it both ways, with sugar and in dough. In the sugar, that determines the amount of bacteria infection, but that don't determine the quality of the bacteria; and in our dough tests we use a very small amount, 200 drams of flour, and determine by the ratio of expansion in the dough, that is under the conditions we are using it. But usually we don't attempt to determine the quality of the bacteria except under some special conditions, but as a rule we have very little difficulty except as I have said from variation of strength. The distiller, so far, has not got any exact method of adding an equal amount of starch and water every time he makes it up, so that they have a variation of starch and water every time; otherwise it is about uniform.

DR. STAHL—Another matter you spoke of, free phosphoric acid in the grain. I suppose you meant the acid phosphate.

PROF. CHIDLOW—Yes, I mean an acid phosphate; that is, free acid.

DR. STAHL—What sort of straw and berry has the macaroni wheat?

PROF. CHIDLOW—It has a large coarse straw, and the most of the macaroni berry is very hard, flinty and of the same size as the other. Some of it is the same size, but the average macaroni wheat is about double the size of the white grain, double. It is very hard, though it usually looks and is something like loose wheat. That is called macaroni wheat because it is used for making macaroni. That wheat comes from Crimea, Russia.

MR. SNYDER—What is the proper temperature for baking bread?

PROF. CHIDLOW—The baking temperature depends upon the size of the loaf. Taking an average loaf, about 400 Fahrenheit.

MR. SNYDER—About how long does it take?

PROF. CHIDLOW—Twenty-five minutes for a one-pound loaf.

DR. STAHL—I thought it was only about 105 Centigrade, that is the loaf itself.

PROF. CHIDLOW—The loaf itself never reaches even 100

Centigrade. Most of our bread, that is the usual household loaf, we bake at about 400 F., with the center of the loaf about 209 to 210 Fahrenheit. Practically the loaf is done when the starch gelatinizes. I have never seen a loaf get as high as the boiling point of water unless it over-baked.

MR. BABBIT—What weight of CO_2 is given out in the fermentation of sugar?

PROF. CHIDLOW—Well, it is about half. The dextrine of the yeast is not fermentable. The amount of starch ferments all the way through.

MR. BABBIT—Is there any good method for determining the amount of starch in dextrine, that is what is the percentage of starch used in the dextrine?

PROF. CHIDLOW—Well, I guess the dextrine being soluable in water would spread or filter through.

MR. BABBIT—That would take three or four days. How would this method strike you? I dissolve known weights of starch in equal amounts of water and I found the colors were not the same. The balance of the starch was a sort of purple with the dextrine. The blue tint corresponded in intensity to between 3 and 5% in the starch. Would that be a probable ratio?

PROF. CHIDLOW—Yes, that would probably be a little bit low.

MR. BABBIT—Well, I could not compare colors. I could only compare the intensity.

PROF. CHIDLOW—In Minneapolis we determined all our starch by weights of extracts. We determined the weight of our soluable extract and then boiled our starch, flour, wheat or offals, and then add a given amount of cold water extract of malt of a known intensity with our boiled starch at a low temperature, running between 130 and 140 Fahrenheit, and then filter that out for one-half hour and take the intensity, and we have failed to get within a quarter of 1% of starch. If we could not get within $\frac{1}{4}$% we would be misleading the mills and could not check up their results. We used to do that very rapidly. We would have to get, with three of us in the laboratory, reports of about sixty determinations of starch, sixty samples from eight to nine and until twelve o'clock, so that it was very necessarry for us to work quickly, and that was our quickest method.

CHAIRMAN—Any further questions?

PROF. CHIDLOW—I would like to invite some of you gentlemen down any time you are at leisure to our laboratory and bakery and see what we are doing. We are located on Thirty-first and Liberty. I am away a good deal, so that I would like to know before hand, so that I would be there. I have only been in the laboratory about three or four hours this week.

MR. CROSS—I move that we extend a vote of thanks to Prof. Chidlow for his kindness in presenting to us this evening his valuable address.

DR. STAHL—How would it be if we arrange some evening to go there and see that in a body?

PROF. CHIDLOW—I would like to do that, and I guess evening would suit you all perhaps better than the daytime. You would not perhaps see some of the doughs being made unless you were there before seven o'clock. They begin making their doughs at four o'clock in the morning and finish all their work about twelve at night, so that the last dough is made from seven to seven and one-half hours before they finish; but I should be very glad to have you all come down some evening.

DR. STAHL—I suggest that we have the Chairman arrange for this visit.

CHAIRMAN—All right, I will arrange that for a later date.

Motion to adjourn carried.

(Paper read before Mechanical Section at its May Meeting.)

CENTRIFUGAL FANS AND THEIR APPLICATION TO THE HEATING OF INDUSTRIAL BUILDINGS.

BY R. B. HAYWARD.

The centrifugal fan in use at the present time is in itself a simple mechanism. The engineer meets it, however, in nearly all lines of his work; so that a study of its operation and application is, it is hoped, always of interest.

The common form of the machine is the housed fan; the blast wheel enclosed in a casing of cast iron or steel plate. This form allows the control of the volume and pressure as conditions demand. A second form, usually called a cone wheel, consists simply of the blast wheel mounted on a shaft supported by suitable bearings; and in its application is placed with its inlet before an opening through which air is to be drawn. Its operation induces the air to flow into the blast wheel, as it were, and leave it at all points on the periphery of the wheel in a direction at right angles to the entrance of the air into the wheel. This form of fan is simply a modification of the housed fan and it is obvious that the air movement is not so easily controlled when originated with this type of fan. Should it be desired to control the air after leaving the wheel it would be necessary to operate the machine in a large air-tight room from which the air leaves through special passages. This application has space requirements that are hard to meet; yet this type of fan has some advantages over the housed fan, as it is obvious that the cone wheel of equal area will handle more volume because of its discharge area at the periphery being unrestricted, consequently permitting a flow of air past all points on its periphery; whereas the housed fan discharges only through the housing outlet. On the other hand, the condition of the cone fan is approached in the housed fan by constructing the housing on a properly formed spiral giving a reservoir space for the air

to accumulate in between the peiphery of the wheel and the housing.

The third form of fan is the familiar disk or propeller type similar to the small desk fan. This fan draws air into itself and discharges it without changing the direction of flow, and owing to the character of the application of power to the work of air movement, the effect of the application does not approach the positive result obtained with the form of blast wheel present in the cone fan or the housed fan. The use of the propeller fan is, therefore, confined to air movements where the resistance of flow is negligible.

The foregoing indicates necessarily the reason for the use of the housed fan in practically all of the cases where low pressure air movements are required. In the air blast for the small forge, the handling of light materials, the conveyance of air for ventilating or for carrying heat units for heating purposes, the furnishing of air for fuel combustion under boilers or heating furnaces, all these require that the movement be confined or controlled in a system of distribution, of which the fan housing is a part; the blast wheel or fan proper being the impelling member that originates the movement.

It is well known that the centrifugal fan has found its greatest use in the field of heating and ventilating large buildings; from the seemingly crude mill building, where it is simply a question of heating, to the schools and other public buildings, where the health and best efforts of occupants require the best methods of heating and ventilation that the engineering profession can devise. There are many good reasons for using the fan or hot blast system for heating large buildings instead of the old method of heating by stoves and direct radiation, and it is not out of place, perhaps, to mention a few of the advantages of the one over the other.

In buildings of large cubical contents spread over considerable area, the proposition of using stoves is out of the question. In a modern factory or mill the floor space that would needs be sacrificed to make a fair showing toward heating with stoves or salamanders would prohibit this method of heating. The endless labor to keep a large number of stoves scattered over considerable

area supplied with fuel, the escape of noxious gases, these and other objections have made it necessary to adopt different methods.

Direct radiation is a method of heating for factory and mill work not uncommon; though it is seldom used now in a modern plant of any size where a thoroughly adequate system of heating is required. The first cost of a direct radiation system is about the same as a hot blast system for small and medium size buildings. The operation is simple, there being no moving parts to care for and a few valves will control its operation. In small buildings of 75,000 to 100,000 cubic contents, direct radiation using live or exhaust steam is quite practicable; but in large modern industrial buildings other considerations make the heating problem assume an entirely different aspect. Direct radiation means the distributing of steam coils or other forms of radiating surface throughout the building. This presents disadvantages that may readily be appreciated. To be most effective this surface should be placed as near the floor line is possible, to counteract the influx of cold air through the opening of doors and natural leakages; yet it is scarcely ever possible to locate the surface in this way, as the necessary free wall surface at the desired points is not available. Further it is undesirable to always use such wall surface, even though it is most practicable from an engineering standpoint. It is not agreeable for a machine operator to stand continuously within a foot or two of heating surface designed to properly heat a space much greater in proportion than the area he occupies.

In some industries the materials used would be damaged by coming in contact with the surface itself or from the water escaping through leaks that are always present. Therefore, more or less valuable floor space is sacrificed. The proper drainage of this system is frequently very difficult to accomplish; waterhammers occur producing leaks involving additional cost for maintenance. Where surface cannot be located near the floor line it becomes necessary to place it overhead suspended from the roof trusses. This is not always possible, and even so, it is removed from its zone of usefulness, for there is no force to effectively distribute the heat, extracted from the steam, to the points where it may properly perform its function. This is true of direct radia-

tion, as a rule, and it is therefore likely to be more or less local in its effect.

It may seem that the above is a departure from the general subject under discussion, but it is intended to assist toward a clearer understanding of the application of centrifugal fans to the heating and ventilating of industrial buildings.

Generally speaking, there are four parts or features to a hot blast system of heating as usually installed in an industrial building, the fan, the heating coils, the distributing system and the driving mechanism. Aside from this there are the matters of steam connections, foundations, location of apparatus in relation to the space to be heated and operation of the system, to be taken into consideration. The fan, as previously stated, is of the housed type and being of steel plate construction appears in many forms. It may be of the full housing type; that is with the housing constructed entirely of steel plate, or of the three-quarter housing type, with the foundations forming a part of the housing; the blast wheel dipping below the floor line into a pit which is made to form a continuation of the standard scroll of the housing. The fan outlet may be tangential to the periphery of the blast wheel in a horizontal, vertical or an angular direction.

The heating surface is divided into sectional coils of various dimensions and containing different amounts of surface. Each section consists of a cast iron base, with steam and drip compartments; the pipe, usually of the one-inch size, being screwed into the base in such a manner that a series of loops are formed between the steam and drip compartments of the base. The pipes spaced lengthwise $2\frac{1}{8}''$ on centres affords a passage for air approximately 40% of the gross area of the face of the section. The sections are made two and four rows wide, each row being staggered with respect to the row in front and behind it; compelling the air currents passing through to be broken up and impign upon the surface. With the common form of base a steam receiver for a series of sections is made by extending the casting beyond the pipes on one end of the base, and forms a section of cylinder provided with flanges. The group, being assembled bolts passing through flanges, forms a complete receiver provided with a single steam inlet and drip outlet. Other forms of bases have individual steam inlets

and drip outlets that are used where refined regulation is desired; the temperature of the air being varied by cutting the sections out or in, the volume remaining constant.

The distributing pipes or conduits for the heated air are usually of galvanized sheet steel construction when placed overhead or of brick and concrete ducts and terra pipe when placed underground. Leaving the apparatus the ducts are of proper size to carry the total volume of air, at a proper velocity, and reduce in area as the proportionate volumes of air are distributed.

There are several ways of driving the fan or impelling member of the distributing system; the particular method depending upon the local conditions. A steam engine either direct or belt connected, the electric motor direct connected or belted, are the usual arrangements employed, and sometimes it becomes expedient to drive the fan from a lineshaft.

The general features of the equipment for a fan system of heating have been outlined, but the most interesting to the engineer perhaps is a consideration of the conditions that affect the calculations employed in the design of an equipment for a particular case and why some buildings require different treatment than others.

If a given building could be made absolutely proof against all heat transmission losses, the heating problem would be insignificant. Under such conditions it would be necessary only at the beginning of the cold weather period of the year to inject a few heat units into the buildings and the heating question would be at an end. Unfortunately, however, for the capitalists and fortunately for those that live and have their being in the heating business, such is not the case. There is a continuous transmission of heat units through the walls of a building, the exterior temperature being below the necessary interior working temperature, directly proportional to the difference between these two temperatures. This is the most important factor affecting the heat loss; but the material of the walls, whether of wood, brick, stone, glass or any of the many materials of construction, together with the character of the exposure, etc., are variables which play their part in reducing the temperature of a building. It is the function of the heating equipment, whatever its character, to over-

come these continual losses by supplying heat units to offset those lost.

Scientific treatise provide us with data in the form of coefficients, representing the heat transmission in units per hour per square foot of surface per degree difference in temperature, for walls and surfaces of given construction and of varying thicknesses. This is available for use with proper allowances for local conditions with heating systems that do not involve a constant changing of the air inside of the building. With the fan system, however, the air is constantly being replaced, unless the recirculation method is used, so that another heat loss occurs through the escape of a certain quantity of air at the interior working temperature. The foregoing therefore gives the items that appear on one side of the calculation sheet of the heating problem. Turning to the source of heat supply the determination of the proper capacity of fan and heater is the item required to balance the preceding calculations of heat losses.

Proper capacity in the fan and heater means, that the heater will so warm the volume of air, which the fan discharges, that the total number of heat units extracted from the steam through the medium of the heating surface and imparted to the air discharged by the fan into the space to be heated, will offset those heat units lost by wall transmission and other causes. Obviously certain limitations and proportions have arisen as the result of direct experiments and experience. Considering the clear or free area between the pipes of a heater section, it has been found that the efficiency of the heating surface is affected by the velocity of air through the sections. The limits of velocities are between 1,000 and 1,800 feet per minute. Beyond this limit any added advantage is more than offset by the increased friction of the air and cost of additional surface, and below this limit the condition of the direct radiator is approached. By efficiency of heating surface is meant the greatest number of heat units that a given surface will give off per unit of time.

The effect of air in motion on condensation of steam in pipes is well known, and therein lies one of the principal advantages of the fan system. Experiments have shown that a given amount of surface properly designed for its duty in connection

with a fan system will condense from three to five times as much steam per unit of time as the same amount of surface exposed to the usually still air of a building and used as a direct radiator. In other words it requires only one-third to one-fifth as much surface with a fan system as with a system of direct radiation; and further the surface is all assembled in a very small space so arranged that proper drainage is easily attained.

The free area through the heater section or through several sections assembled remains constant through the depth of the heater. The air passing naturally increases in temperature, but not in direct proportion to the depth; in other words the sections that receive the air last are not as efficient as the first sections, because there is less temperature difference between the steam inside the pipes and air outside than with the first section; the steam pressure upon the entire surface is the same, consequently the same temperature all over the interior of the radiating surface. This falling off in efficiency obviously defines a limit to the depth of the heater or number of rows of pipe that the air should pass over. The standard depth of heater for the kind of buildings under discussion is twenty rows, although there may be some variation either way.

The standard heater therefore consists of 1″ pipe spaced so as to give 40% of the face of a section as clear area and in depth approximately twenty rows. Careful observations and tests have shown that surface arranged in this manner subject to air velocities within the limits previously mentioned has a condensing capacity per square foot of 2 to $2\frac{1}{2}$ lbs. of high pressure steam per square foot per hour with the initial temperature of air reasonably low. This is affected by other variables such as actual velocity through heater, initial temperature of air and the specific steam pressure. Knowing the radiating capacity of heating surface per unit of measurement, from the previous calculations of heat losses the amount of surface may be determined. With the properly calculated surface the size of fan required is that machine with sufficient capacity to produce the proper velocity through the selected heater.

The selection of the proper fan presents another very important problem. A machine running at a high rate of peripheral

travel will deliver the required volume, but a larger machine running at a correspondingly less rate of peripheral travel will also perform the same duty. Consulting the capacity tables for various machines at varied rates of peripheral travel, the desired volume is found in a machine operating at 1½ oz. pressure a peripheral travel of approximately 6,300 feet per minute. The same capacity is also found in a larger machine at 1 oz. or 5,100 feet travel per minute, and still a larger machine operating at ½ oz. or 3,650 feet travel per minute. The second and third machines are operating against 2/3 and 1/3 of the pressure, respectively, that the first machine operates against, yet all are delivering the same volume: consequently the second and third machines consume 2/3 and 1/3 of the power, respectively, that the first machine requires for its operation. Apparently the third machine is the one to be selected. The requirements of heating, however, are by no means constant, and although heating plants are designed for zero weather conditions, there are a very few days throughout the year that the maximum capacity is required. A fan selected to operate at 1 oz. speed for maximum requirements would actually operate btween ½ and ¾ oz. pressure for practically all of the time, in this section, although the reserve capacity is present when required. In view of this it is practice for factory heating to select fans operating at 1 oz. pressure for maximum conditions, as the increased cost and interest for a fan to perform the maximum duty at ½ oz. would more than offset the cost of additional power to operate the smaller fan during a few zero days throughout the season. The space limitations would further affect the determination of fan size.

The methods of determining proper capacity of apparatus by means of transmission losses and radiating capacity of heating surface is the ultra scientific method undoubtedly, although it is subject to many variations that cannot be accurately determined. It will be readily admitted that to even measure all of the wall and roof surface of an ordinary mill building, to determine its amount, character and proper co-efficient under existing conditions, besides other factors of equal importance, would be rather impracticable and frequently decidedly inconvenient. In view of this the engineer engaged in this line of work can consistently

swallow his profession pride and adopt methods which, while not so scientific perhaps, are equally as accurate.

The common method for calculating for factory buildings and practically all kinds of buildings, in fact, is based on air changes per hour. The practical arrangement of heating surface has been outlined and the resulting temperature of air at various velocities and steam pressure observed. With a velocity through the heater of approximately 1,800 feet per minute, steam at 5 lbs., initial air temperature at zero, the resultant temperature will approximate 125 degrees. This will be increased to 150 with high pressure steam or the resultant temperature at 5 lbs. pressure will increase should the velocity be lowered, and in either case the resultant temperature is affected by the temperature of incoming air. Every size of fan calls for a given size of heater at the fan's predetermined speed for maximum conditions. With this data well in hand, it is quite expedient to standardize experience into methods of calculating on the basis of air changes per hour. It is here that, as in all other lines of engineering, sound judgment based upon experience becomes an important element.

The rate of air change for factory buildings ranges from once in twelve minutes to once in forty or even sixty minutes. The small poorly constructed building, with cubic contents of 100,000 cubic feet or less, exposed to high winds and subjected to a constant opening of doors and other leakages, calls for the extreme. On the other hand the mammoth structures seen to-day, with acres of floor space under one roof, require but the other extreme in the way of heat supply to maintain the proper working temperature. These large buildings sometimes run as high as 20,000,000 cubic contents, in which case the ratio of exposed surface to cubic contents is vastly different from that of the small building. Then, too, the best construction is used; brick walls, slate roof, and although the glass area is considerable for the purpose of light, windows fit well and chances for leakage are reduced to a minimum. Between the two cases just mentioned come the moderately sized fairly constructed building that requires different treatment, which is usually a twenty to twenty-five minute change.

The location of the apparatus with respect to the space heated

is considered with the view of a position as centrally located as possible. This affects the cost of the distributing system materially. With heat distributed from the center of a rectangular building, for instance, in preference to the end, a saving of 25% is made in the cost of the distributing system; and as the cost of distributing is sometimes one-half of the entire cost, or even more, the saving is considerable. Other considerations have their influence, however, such as proximity to source of steam supply, a desire to have the heating plant near the main power plant, and the general physical characteristics of the building. Too many times the heating plant is compelled to shift for itself, due to lack of care on the part of the engineer of the works to give its importance due weight. Usually it is the last thing to be considered and is taken up when the funds are low, the result being that it is crowded in some way or other, which should not be, for when its use is required it is really the key to the operation of the establishment, and its failure means many times the interest on the cost of a well designed, well installed heating plant.

The question of air distribution is one that has caused a great deal of discussion, and there is a wide variance in opinion and in practice. A building of several stories, ceiling ten to twenty feet high, can frequently be heated satisfactorily from a central standpipe blowing the length of the building for distances of 100 to 150 feet, when the building is fifty to seventy-five feet wide. The ceilings tend to confine the air and diffuse it sufficiently. A machine shop of the gallery type may be treated perhaps in this way with limited distribution by blowing the air lengthwise of the lean-tos under the galleries. But if the building is not reasonably tight or subjected to frequent opening and closing of doors it is necessary to distribute properly throughout and especially to those parts affected by steady and intermittent inflows of cold air. The design of the distributing system is affected by the recirculation method of operation. If all of the air is taken from outside of the heated space there is an equal leakage from the building that materially prevents the inflow of air; and a much better distribution of heat is obtained with limited distributing pipes than when the air is all or in part returned from the building. It is practically always desirable to recirculate the

air in industrial heating, ventilation not being a factor, because of the economy in steam consumption. In a very leaky building it becomes desirable to use a large percentage of outside air in order to overcome the drafts due to leaks; the same apparatus, although apparntly inadequate when returning the air, has properly performed its duty with all outside air, although more steam would naturally be condensed in the latter case. A particular installation showed a temperature increase of 20% when using outside air entirely, the building being very leaky and subject to continual opening of doors. The situation was further complicated by the presence of exhaust fans drawing material from the mill, consequently air; the exhaust fans having about 60% of the heating fan capacity.

High shop buildings require an extensive system of distribution to thoroughly spread the heat before it can rise from the floor and be lost, so far as properly performing its function is concerned. Not only should the main branch pipes be carried to extreme points, but the outlets should be carried down within a few feet of the floor line. The idea is simply injecting heated air into a room thirty or forty feet high and depending upon its properly diffusing is not founded upon a proper conception of the situation, especially where the recirculation method is used with apparatus in the same room. This is an extreme case, but it is nevertheless intended to cover all arrangements of limited distribution through grater than thirty feet from main trunk pipe where buildings of the above height are treated. The reasons are obvious and practical examples may be cited to substantiate them.

The railway paint shop is a problem that requires careful treatment as to distribution. The working temperature should be about 70°, with air distributed evenly to all parts, insuring equal heat, low velocities of discharge, to avoid suspension of dust and dirt in the air, that may be deposited on a freshly painted surface. Besides the primary object of heating in a paint shop, the fan system assists in the rapid drying of paint by circulation, and the unavoidable ventilation accompanying this method of heating has an opportunity of being utilized.

The locomotive round house presents an interesting phase of the question. The air is usually discharged into the pits on the

side or end. The general purpose is to heat the building, but the great specific use of heating apparatus is to rapidly rid an engine of its snow and ice, so that it may be quickly overhauled and made ready for another trip; an important matter in these busy times for the motive power department of our railroads. By the constant circulation of air the house is also kept free from smoke and vapors from the engines. The conditions surrounding a particular house enter largely into the determining of proper heating capacity aside from the cubic contents, construction, etc. It must be noted whether the house is a busy one, that is whether engines are constantly going in and out, and whether doors are likely to remain open long for any purpose whatever.

The distributing system for a round house may be overhead sheet iron pipes or underground brick or concrete ducts. If the roof truss has a center supporting column the overhead system may be used with drop pipes at the columns to the floor line and underneath same to side or end of pits. There are, however, objections to the sheet iron, as it is likely to deteriorate very rapidly because of the gases from the engines, and the drop pipes at columns are sure to be damaged by being in the way of tools and appliances in the repairing of engines. The heating apparatus is always located in a separate house at the outside circle of the building. A simple distribution is accomplished by running an underground duct straight to the inside circle and extending it around this circle, entering pits with branch pipes at the tender end. Entering pits at the end instead of at the side might appear impracticable, but it has proven fully as effective as the other method. In view of this there is every consideration for using this method, as the circumference of the inside circle is about one-half and two-thirds of the outside and central circle, respectively. This greatly reduces the cost of ducts and distance for blowing air.

There are many varied problems aside from those just mentioned that require a full knowledge of the affecting conditions before the solution of the heating question can assume a successful result. The paper mill, the textile mill, the foundry, tannery and others that may suggest themselves, each require special treatment.

As to the advantages or disadvantages of the overhead or

underground distribution, the one opposed to the other or vice versa, the conditions are the usual solution to the question. The overhead system is more common, principally because it is cheaper than the underground; and although the heating is usually forgotten when the building is designed and other equipment is laid out, the piping can be arranged for in some way, even though the scheme may not be as simple as it might have been had the matter been attended to in due season. Underground ducts, although more expensive, because of frequent expensive excavating and other reasons, have their advantages. They may be necessary also where all floor space is covered by traveling cranes. They are permanent in character and are entirely removed from sight and possess the great advantage of delivering heat where it is the most effective, at the floor line or slightly above it.

The design of the proper area for the mains and branches of a distributing system is a comparatively simple matter. The main trunk is usually made equal in area to the fan outlet. Fan outlets bear such a relation to the capacity that a velocity of 2,500 per minute is present in the main trunk at 1 oz. speed. The desirable branch outlet velocities range from 1,000 to 1,800 feet per minute. The unit space being determined, the branch pipe is of proper size to give the desired velocity while carrying the proper proportion of heated air for that space. Friction is allowed for by gradually decreasing the velocity in the main ducts as they recede from the fan. In an undivided space to be heated the outlet pipes are of a uniform size. A short method in this case is to make the total area of outlets 25 to 40% greater than the fan outlet. The trunk sizes are then computed from the outlets back to the fan or the outlet areas. The same results are obtained as when areas are based on velocities. As a matter of fact any system of distribution may be figured in this way, even though the space is cut up and not uniform.

A direct connected steam engine is usually the most desirable way to operate a heating fan for a factory building, because the speed of the outfit can be varied at the engine throttle to suit the weather conditions. The matter of temperature regulation is, therefore, very simple; a desirable condition to attain. Engine driven fans are desirable unless it would be necessary to carry the

live steam for engine a long distance, although plenty of exhaust steam is available for heating purposes near at hand. Of course where there is insufficient exhaust steam for heating purposes a steam engine is far preferable to a motor, as the engine exhaust is utilized for heating, practically eliminating the cost of operating the fan. It may appear that where plenty of exhaust steam for heating is available an electric motor would be more economical, because a unit of power can be generated far more economically in a large generator than it can in a twenty-horse power steam engine for instance. But consider the fact that the average power consumption through the season is about 60% of the maximum load. The engine can adjust itself to take advantage of all weather variations. On the other hand the motor must not only be proportioned for the maximum speed, but must operate at that speed or what amounts to the same thing so far as power consumption is concerned, for some of the current must be dissipated in a rheostat to cut down the speed. It is true volume dampers might be placed in the main air ducts to cut down the fan delivery, thus cutting down the power required, but these dampers would never be operated. An engine driven fan is also independent of the main power plant, and it is possible to heat the building nights and Sundays when the main plant is usually idle.

With large floor areas under the same roof it is desirable to break up the heating apparatus into units where possible. It is also frequently necessary, for the requirements exceed the limits of fan sizes. The unit arrangement simplifies the distribution, avoids large duct sizes, and in mild weather one or more units will perform the duty. Under such conditions, other factors being eliminated, electric fans are desirable. The matter of ventilation has not been touched upon, although it is an unavoidable accompaniment to the fan system of heating. It is seldom considered in connection with factory heating, as the natural inflow and leakage is sufficient for all practical purposes. If it is necessary where the number of operatives is large, it is a simple matter to arrange to take some air from out of doors or all, in fact. However, the plain fan system heating plant is frequently able to greatly relieve conditions during uncomfortably warm weather, either by

placing outside air into the building or simply keeping up a circulation of inside air. The coils may even be used for circulating cold water if a supply is convenient; this may be an expensive adjunct for the short time of use, but the result is effective.

Pointing out the advantages of the fan system over others, although possibly it is unnecessary, the convenience of operation is readily apparent; the whole system can be controlled from a central point; the heating surface is centrally located in a small space, so that positive drainage is insured, avoiding leaks and the resulting damage. The heating surface is made most efficient, reducing the amount. The heat is distributed evenly, insuring a uniform temperature, and the workman has no excuse to lose time standing around a radiator or stove. Although ventilation is usually unnecessary, it is always present when desired, and it is not an expense when undesired.

Although the discussion has been limited to the one topic of factory heating, this represents really the simplest form of hot blast heating. School buildings, church edifices, theaters, court houses, in fact all types of public buildings demand all the refinement of the art. The matters of adequate ventilation, temperature regulation, air filtering devices, noiseless of operation, both in the machinery itself and air velocities in ducts and registers, economy, all these factors complicate the problem and require the most careful study and treatment on the part of the designing engineer. The mere fact that all of these demands may be met indicates the comfort-giving, likewise sanitary qualities of the system, which, together with the simple factory heating problem, substantiates the claim of great versatility for the fan system of heating and ventilation.

DISCUSSION.

MR. GIFFORD—I have in mind being at an engineering meeting some years ago where a gentleman presented a very able paper on this subject. He, however, through lack of experience in this system, suggested that the way to heat a building was to practically eliminate the distributing ducts. Anyone at all thoughtful on the subject could see at once that, generally speaking, that is an unsafe thing, although in instances that can be

done very safely. But I think the province of the engineer first is to present an engineering proposal. I think he should design a system which is not only effective, but in his best judgment is going to be efficient. You can readily see that in a building, many of which we have now, perhaps eighty feet high and a very large area, that simply blowing air in at one end and expecting it to do effective work, the work all being about eight feet above the floor, is wrong; therefore, it is only necessary or desirable that the air should be put where it has to do the work; and I was taught that where you want a thing in any particular place it is wise to provide a conduit to get it there. I have in mind a building about eighty feet high, of which they wanted to heat about one-half the length, and they wanted a guarantee that if we didn't get it just that way they would not have to pay for it. I took a long chance on that and arranged four compartments at one end of the building and had an ample system of distributing pipes, the air being carried lengthwise through the building under a screen and carefully worked out, the air brought down about eight or nine feet from the floor and discharged towards the floor with the idea of heating about seven or eight feet high; then we proposed a partition about twelve feet high across the building at a point beyond which it was not desired to heat, and when passing through the end of that building it was almost the same as when going from in-doors to out-of-doors. I think this is, perhaps, the most extreme case of this particular kind I have ever seen, although I have frequently in connection with some of my work, stated that $50.00 worth of distributing pipe, properly arranged, will, within reasonable limits, eliminate the necessity for $100.00 worth of increased size of apparatus, and I think that, in practice, is confirmed. Besides all this goes the question of the "man behind the gun." If he actually were of an inquiring mind and should investigate the subject and know, as engineers in these days do know, the result, he would be appalled and he would not have any more of those kind of systems. Now I think, speaking of what an engineer does know to-day, it is a hopeful sign at the present time, although it is somewhat inconvenient to us old people on the subject, who perhaps change our ideas slowly, that there is such an investigative turn as your Society is evincing. It

is tending a great deal towards the development of the floor system of heating; I think really it is that very manner of the accomplishing of certain things by the expenditure of a minimum amount of energy that is the main and most important thing. I have in mind a plant in Pennsylvania here, where, for a certain purpose, there were a large number of fans in operation that required something between 500 and 600 horse-power. When the question of a guarantee came up we guaranteed to take out one-half of that plant and in its place put in a plant that would take a hundred horse-power plant. It was done and so successfully that a second plant was installed, practically a duplicate of the first, to do 25% more work than was previously done with higher horse-power. It is no miracle, but simply the result of the necessity that compels a man to be alive in his business.

CHAIRMAN—Is there anyone here that has had some experience of heating by centrifugal fans?

MR. CAMPBELL—I might say we have had some experience in heating with electrically driven centrifugal fans. We have used a system in general the same as outlined, except as to the heating medium, hot water was used instead of steam. The heating entries in the various buildings were provided so as to distribute the air to best advantage. The water is heated in large condensing heaters in the power house. All the exhaust steam is made use of and in very cold weather it is supplemented with live steam. The water is continually circulated throughout the plant, perhaps for half a mile from the power house, and is kept at a certain temperature, depending upon the temperature of the outside air; consequently, after the system was once regulated, any particular building could be kept at a fairly uniform temperature, which was made to suit each particular building. Every building was not made the same temperature, but some buildings were made warmer than others. For example, in the paint shop 70° was maintained, and during this past winter that figure could be maintained without any trouble whatever. The outside temperature ranged anywhere from zero to 50°, by varying the temperature of the circulating water, and making use of, in addition to that, the usual arrangement for shutting off certain heating stacks and for varying the amount of air taken from the outside. Speak-

ing of the advantage of drawing air from the outside of the building, we also had a very forcible example in the round house. We put in there a fan which had a capacity of something like 40,000 cubic feet of air, drawing air from inside the building, but on account of the construction of the building it was practically like heating all out-doors. The round house was a very active one and the doors were very frequently open. Besides this there was a continuous monitor on the roof near the outer circumference with windows on each side, swinging at right-angles, and consequently an immense amount of air was let out. Sometime before next winter the general arrangement will be changed, air will be drawn from outside and in larger amount. The question of fans again came up to determine whether the present fans could be made to properly heat the building, and it was found they could, but the amount of power consumed would be decidedly excessive; consequently the fan will be taken out and a fan approximately $2\frac{1}{2}$ times as big will be put in. The amount of heating surface was not quite sufficient and that will also be taken care of. This particular building is heated by using the duct on the inside circle, as mentioned, and delivering it in the pit. The author of the paper for the evening mentioned that the efficiency of the heating surface of the inner rows of cribs was not as great as that of the coils first struck by the air. That may be, of course, correct, but heat taken out per square foot per degree difference of temperature between the air and the steam or water would, I think, be the same no matter whether you take the first or the twentieth coil. To find that out we made a number of experiments and found, allowing for the expansion of the air, that we got practically the same efficiency from the last coil as we did from the first coil, when considering transfer of heat per one degree difference of temperature.

CHAIRMAN—At what temperature does the water pass through the coils?

MR. CAMPBELL—The temperature of the water passing through the coils at zero weather is 206°, according to the schedule we put in force, and that varies down to about 160° as the outside temperature raises. I might say that the Terminal station is also heated by the same general system, except that the air is

for ventilation only; the additional heat required is supplied by direct radiation. All last winter the fluctuation of temperature in that building was not more than $1\frac{1}{2}°$. My remarks apply to the Pittsburg & Lake Erie shops at McKee's Rocks, and the Pittsburg station.

CHAIRMAN—You spoke of some constants, Mr. Hayward, for the conduction of heat through the different surfaces. That is, different materials. What would you recommend?

MR. HAYWARD—Our people have published a treatise here on the question of ventilation and heating and there is a little list given in here. I think these constants are some that were determined by the German Government and we have had them transformed to American units by Mr. A. R. Booth, an American engineer of New York City; and a few of those coefficients, or constants, are given here, but, as I stated, they are to be used with a great deal of consideration.

MR. JAMES—I should like to ask Mr. Hayward about the ratio, approximately, in which the pressure varies with the speed. He speaks of different devices for reducing the speed. I understand from the discussion, as well as from the paper, that to lower the temperature other devices than a reduction in the speed are used, such as reducing the number of stacks, or pipes, or the temperature in those pipes, and the proportions of air taken from the inside and outside; and I should like to get an expression from Mr. Hayward, roughly, how much they vary this speed. Do they reduce it one-half, or do they redudce it one-quarter? I appreciate that it is not the same in every case, but what I wish is a general expression.

MR. HAYWARD—Well, of course the weather varies very considerably, and it is simply a question of adjusting the speed of the fan to suit the weather conditions; that is the ordinary method of operating a fan system of heating as installed in factory buildings. There is really no rule for determining the speed of the fan, but it is simply a question of—I am sorry to say—not very much science, but simply a question of going ahead, and if anybody kicks we turn the valve on the engine and make it go a little faster. With the ordinary system it would be considered more desirable to regulate the speed of the fan than to cut out

one or two sections. By reducing the speed of the fan we reduce the amount of power required, and we would save more that way, I think, than by cutting out one or two sections, because these sections would be using exhaust steam anyway. But there is no specific way of regulating it, except the conditions and the temperament of the man in the building.

MR. JAMES—That doesn't get at what I want. In other words, is the velocity in proportion to cube of the speed? Is there not a maximum speed and also a minimum speed beyond which it is not economical to run the fan?

MR. HAYWARD—The volume varies directly as the speed, and the pressure varies as the square of the speed, and the horse-power required varies with the cube of the speed. For instance, if we are operating a fan with 100 revolutions and it takes two horse-power, and we double that speed, we have to multiply our pressure that we get by four, the power required would be eight times as much. The volume varies directly as the speed of the fan, the pressure varies according to the square, and the power varies in accordance with the cube of the speed. That can be traced back, I believe, similar to the law of falling bodies. The loss in the ducts does not enter into it. It is simply a matter of practice in proportion to the ducts. If they are made large enough there would be practically very little loss in the ducts. It depends upon their size.

MR. STUCKI—Mr. Hayward mentioned that to each size fan belongs a certain size of coil. However, we used alternate sections for exhaust and live steam. Now it looks to me that possibly in using exhaust steam only we had a coil only half as large as we should have used for that sized fan, provided the combined evil was proportioned properly. Therefore, I would like to know whether it is correct to follow that system and to use certain sections for exhaust steam and at all times, while other sections are reserved for live steam in severe weather, or would it be better practice to use at all times the same number of sections for that certain size fan?

MR. HAYWARD—We are using exhaust steam or live steam; the live steam heater is not as deep, as the air does not pass over as many coils, because the steam is of a high temperature.

MR. GIFFORD—In answer to the question, it would seem to me thus: That primarily the area of the coil is to be determined by the amount of air that is to be moved over it, regardless of whether you have the conductor or not. What would result by the use of steam, whether live or exhaust, would be the temperature effect upon that area; or in other words, as shown in Mr. Hayward's paper, if we put twenty coils with exhaust steam we would get a temperature of approximately 125°; if we made, suppose a high pressure steam, we would get approximately 150° temperature, depending, of course, upon the inital conductor of the air, that is assuming that it would be about zero; about 30° above zero would add 15°. Of course the final temperature is not increased in proportion as the initial temperature is increased. It would be somewhat less. But so far as the size of the coil—I believe the gentleman refers to the area of the coil—that would be determined primarily by the question of how much air you could get over it. One thousand and eight hundred feet is considered practical velocity of the air over a heater. Now, if that is increased to 2,000 feet per minute, naturally the more rapid passage of the air will not take up proportionately so much heat, but because the velocity is higher it does not detract from the added heat as much as it adds to the heat when you reduce it 200; or, in other words, theoretically an increase of 200 feet velocity would reduce the temperature 5%, and, theoretically, the reduction of velocity would increase 15%. Practically, it is not any cause of the higher velocity. It is very difficult to get heat into the air, and it is likewise difficult to get heat from it, because it passes into it slowly and it is given out slowly. As for suggestion, let us say that if theoretically the temperature would be reduced 5% by increasing the velocity to 2,000, practically it would not reduce it over 4%, whereas a reduction of the velocity, which would increase the temperature, would probably hold up the 5%.

MR. STUCKI—With regard to the entrance of air into the room, Mr. Hayward has mentioned it is good practice to enter it about eight feet from the floor all around the building. I know many shops equipped that way, and in some of the paint shops the air is removed through openings in the floor and forced back through conduits to the engine room. Here it is mixed with

fresh air, reheated and recirculated. But in several school buildings I know the air enters the rooms just at the ceiling and is taken out at the floor, as mentioned before, but right in front of the windows. I suppose this is done so as to take hold of the cold current which drops naturally at the windows and to prevent it from striking the children. But it is not exactly clear to me why the air should enter at the ceiling in a school building and near the floor in the shop.

MR. GIFFORD—If I understand what has been said, it is this: In the heating of a school building the cubical space usually allotted per occupant is about 225 feet, that has become more or less of a standard. The State of Massachusetts was the initial State to take action upon the question of ventilation and they appointed a committee who decided upon this space; it is considered around the country that it is a law. It is not a law, but a privilege given the State Board of Police. It just recalls something: A gentleman was asked by the State Board of Police to write the necessary requirements for the fan system and he proposed that they should give their pupils fifty feet of air per minute. He was a little in doubt after he wrote this out and he came to me and I saw at a glance that it would simply blow the people out of the room. A change of air about once in eight minutes and sometimes once in six is the limit of possibility in introducing air into the room unless you should have it perforated in the top and bottom. It is impossible to get a more rapid change than once in six, or probably eight minutes. As they bring the air, usually, into the room at one point it must come at a high velocity. Therefore, it is necessary to get it above the heads of the occupants and allow it to divide itself and spread out over the room, and by given direction from two causes, one the leakage through the doors, etc., and the other through the provided ducts for going out. The other point is, in the school room it is brought in horizontally, whereas in the shop it is brought in vertically. If the egress of the air was kept over the head the air would not come to the floor, because it has the same efficiency to rise as though it came off the hot steam surface. Theoretically, of course, the proper way in a room having a large number of occupants is to bring the air in below through a perforated floor and

out through the ceiling. The rule, however, that upward ventilation where the air is heated in transit, as it passes through by contact with the bodies in it and by heat given off, etc., would be a very theoretical way of doing it. Carbonic acid gas given off would go to the floor, so in a school room air is brought in horizontally at the top of the room. I think drawing it out under the windows was an accident. Usually, if it was a room like this, the air should be brought in here and distributed lengthwise and then back and out very near where it came in, except at the floor line instead of above. In a factory system the air is brought down and distributed vertically; this is compromised because the place is occupied by tools, and if there is any inconvenience it generally is one machine or so, so that in both cases I think the principle is correct, although the application is really quite different. In regard to the question of speed at which a system would operate, I think it would depend very largely upon the question of whether you did or did not have an ample system of distribution. If you had pipes up here thirty or forty feet high, and it being desired to bring that air to the floor, the air to operate that would have to come off the steam supply. I think that would be the determining feature rather than almost anything else. I have in mind a railroad shop in the West put in twenty years ago where, except at high speed, the air passed out of the pipes and went out around the top of the building; it was 90° at the top when water on the floor froze.

Mr. Stucki—Mr. Hayward has mentioned cone-wheels. Are they much used for heating and ventilating buildings? Would also like to know to what extent the coils are used to cool the air during the extreme hot weather.

Mr. Hayward—It is used to a limited extent, but not anywhere near as much as the ordinary fan wheel. It is a great deal like the ordinary blast-wheel. In regard to the water circulating in those coils, I only know of one case in my experience where that was used, and I think it was effective in that case, and there the particular conditions made it very cheap for them to use it. The building was located at the foot of a large hill and there was a very nice spring up the hill; it was a very easy operation to keep those coils cool with the water circulating through them. In the

summer time it was very effective. I simply mentioned that as a possibility.

CHAIRMAN—If the water were allowed to trickle over the pipes that would produce considerable cold, would it not? The water would evaporate into the air and thus cool it.

MR. HAYWARD—Yes; we have a common tower arranged with simply a stack about 18″ wide built up with an angle iron frame where the water is allowed to trickle down over the top of that, and at the velocity we usually install them it was found the air will come down to 10°. It was found to be very effective for cleaning as well as cooling the air, but it would not be practical, of course, in ordinary factory buildings, such as laundries and that sort of thing.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundredth and forty-sixth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, June 21, 1904, at 8:20 P. M., Vice President G. E. Flanagan in the chair. Forty-one members and visitors present.

The minutes of the previous meeting were read and approved.

The Board of Direction report that they had approved the following applications for membership and present same to the society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
W. E. BENTLEY,	Sales Agent, Rust Boiler Company, h., 5 Colonial Annex, Wilkinsburg, Pittsburg, Pa.	Henry M. Wilson, L. F. W. Hildner, F. S Rice.
JAMES G. CHALFANT,	Ass't Engineer, Bureau of Surveys, Pittsburg, Pa., h., St. Clair and Callowhill Sts., Pittsburg, Pa.	Geo. S. Davis, Emil Swensson, Willis Whited.
ROY K. CRAMER,	Secretary, Jutte & Foley Company, 32 Conestoga Bldg., Pittsburg, Pa.	W. M. Judd, H. G. Shaw, Louis P. Blum.
ADAM E. DAUM,	President, Pope Cement & Brick Co., 421 Wood St., Pittsburg, Pa.	Frans Engstrom, G. E. Flanagan, J. M. Camp.
ROBERT GORDON GREGORY,	Pgh. Manager, The Lagonda Mfg. Company, h., 2 Everett St., Wilkinsburg, Pa.	R. A. Cummings, Chas Worthington, J. M. Camp.
JOHN FREDRICK JOHNSON,	Special Engineer, Pressed Steel Car Company, P. S. C. Co., McKees Rocks, Pa.	Frans Engstrom, J. M. Camp, Chas. Worthington.
ALBERT A. LANE,	Engineer, Taylor, Wilson & Co., Ltd., h., Grant Ave., Allegheny, Pa.	F. V. McMullin, Sam'l E. Diescher, C. H. Sample.

FRANK R. LAYNG,	Ass't Engineer, Bessemer & Lake Erie R. R., h., Greenville, Pa.	Geo. T. Barnsley, J. M. Camp, Sam'l Diescher.
CHAS. A. LINDSTROM,	Chief Engineer, Pressed Steel Car Company, h., 35 Library Place, Allegheny, Pa.	Frans Engstrom, J. M. Camp, Chas. Worthington.

It was moved and seconded that the Secretary be instructed to cast a ballot electing these applicants to membership.

MR. FLANAGAN—There being no further business we will now listen to the paper of the evening:

SAFEGUARDS IN BITUMINOUS COAL MINING.

BY W. E. FOHL.

"Experience is a good schoolmaster, but his fees are heavy." A long and eventful history lies back of the mining industry of to-day. Some of its lessons have been acquired with lavish expenditures of concrete human effort and that great potential energy, Capital. Too many of them have been learned at the expense of human life.

This industry is so woven into the fabric of human endeavor that it must continue at any cost. It behoves us then as conservators of energy to scan well the dearly bought lessons of its history. If they have been sufficient to allow us to avoid the catastrophes that occur from time to time, we must fix them well in our minds. If they leave problems still unsolved, for them solutions must be sought. Almost, if not quite, enough knowledge exists to avoid the known dangers. The difficulty lies in the fact that the sum total of this knowledge is not shared by all of those whose lives and capital are at stake. With so much that is vital at issue, these lessons must be gone over carefully and repeatedly, and the most trivial features of them stamped indelibly on the memory of those in interest. In this industry, above all others, every man is "his brother's keeper." It needs in many cases but one imprudent action, or the neglect of one apparently trivial precaution, to bring down destruction upon innocent and guilty alike.

It is not to be expected that all of the intricate details of this industry should be thoroughly understood by every individual engaged in it. There must be rules, however, laid down by those having the requisite knowledge and experience, and this has been attempted in legislative enactments by the various states in which mining is carried on. Prominent among these is the Act of 1893 of the State of Pennsylvania. This was formulated by a special commission composed of nine inspectors, nine operators and nine

miners. As is well known, the Mine Inspectors of the State of Pennsylvania are selected by competitive examination from a large number of applicants. The mine operators were men with an intimate personal knowledge of mines and the methods used in their working. The miners were recommended by their labor organizations and were worthy representatives of their class. It would be difficult to improve upon the personnel of this commission, and the Act is a monument to their good intentions and sound judgment. Some liberties were taken with it after it had passed out of their hands into the hands of the legislative committee. Some of the changes made were for the better, but some others were decidedly for the worse. It is, however, the most comprehensive one attempted in the United States, and has served well its purpose. Its smooth working goes far to show that its scope could safely be very much broadened, and that many of its provisions, which are now merely suggestive, could be made specific and mandatory to the great benefit of all engaged in this industry.

In the writer's opinion the time is ripe for a remodeling of this law, and it is hoped that some of the suggestions advanced in this paper will show the necessity for this. This movement should be, at the least, general enough to include the States of Pennsylvania, Ohio, West Virginia and Maryland. In fact the conditions attendant upon the mining of bituminous coal are everywhere so nearly alike that no sufficient reason can be advanced why the laws regulating the same should not be uniform throughout the nation. This paper will make no attempt to say finally what should be the changes made in the various legislative acts. It goes without saying that this can be done by no one man. It should be the work of a carefully chosen commission, given ample time to investigate the numerous and important experiments made abroad, and with sufficient money to continue some of the more important experiments under the conditions existing in the United States.

I wish to emphasize particularly this need of uniformity. The final marketing of the product brings into competition coal from many different states. Close competition renders inevitable and natural a careful scrutiny of pay rolls. If laws are more

stringent in one locality than another, it is then readily apparent that this stringency is the cause of increased cost of production. When this is once shown, no matter how good the intentions, the effect will be that the law will be liberally, and in many cases, loosely interpreted. A great number of the miners, too, are of a roving disposition. These, as a rule, are the least intelligent; and it would seem to be of primary importance that rules regulating conduct in mines should be uniform and their infractions easily punishable, in order to firmly fix their observance in the habits of this floating contingent.

The first draft of the Act of 1893 of Pennsylvania contained the provision that the mine workings should be laid out by the mining engineer, the mine superintendent, and the mine foreman, in conjunction. As it now stands no provision is made for a preliminary inspection of mine layouts, and many exist that show conclusively the work of unskilled minds and which contain features detrimental, both to the welfare of the miners, and to the interest of the people whose capital is invested therein. The law, however, regulates the number of men who shall work in any one split of the air current; and, in conformity with this, mines have been laid out variously with double, treble and quadruple entries. Many operating companies have, at considerable expense, carried the matter of the mine layout and development to a high degree of perfection. In this matter, as well as in many others, some of the leading companies have gone far beyond the limits set by the law.

The layout should be based on maps made from accurate surveys, with exact locations of all prominent surface features. Surveys without error are, of course, a physical impossibility, but with the instruments at the command of the modern surveyor, i. e., the transit, fitted for measuring vertical angles, and the 1,000-foot tape, surveys have actually been made with an error of but 6/10ths of a foot to the mile. It would seem entirely feasible to assign some limit of error by law, even though the standard might not be so high as above indicated; and a critical examination of the maps to determine their accuracy would be a simple matter. When lands belonging to the Commonwealth of Pennsylvania are surveyed, and patents issued, it is required that the actual calcu-

lations of their boundaries and areas shall be submitted to the State officials. It would seem important that surveys upon which may depend the lives of the State's citizens should receive at least as much consideration, and this assumes special importance in sections where the coal veins are penetrated by oil and gas wells. The surveys of coal lands should be checked in a similar manner and, before any work is started, a plan showing the proposed layout should be examined to test its conformity with the mine law.

On the subject of ventilation, probably more time and thought has been spent than on any other one subject connected with mines. Here, too, the laws are not specific enough, and too much is left to the discretion of the individual. Without entering into a detailed discussion of this, it would seem advisable that hoisting shafts and haulage ways should always be the inlet for fresh air, regardless of the season of the year, and all return air ways should be rendered inaccessible to any but properly constituted officials for the purpose of examination, the purpose of this being to preclude all contact with the vitiated mine air, except in the actual working places, and there, only within the confines of a well defined split of the air current, which, after having served its purpose, should be conducted into the inaccessible return, where no one who is ignorant or careless of the danger it contains may turn loose its destructive properties.

The reversible fan may have a very positive value in the case of accident, but in many instances it is now used to reverse the current of air, to suit the seasons of the year. The principal reasons for this change are to prevent, in wet shafts, the accumulation of ice in the hoisting shaft, and to make the temperature more comfortable at the shaft bottom, for the men at work. This change of air current with the seasons is, to a certain extent, a survival of the times when it was difficult to secure sufficient ventilation with the apparatus available. At the present time very few mines of any considerable size are opened without provisions being made for fans that have a capacity of any where from 200,000 to 500,000 cubic feet of air per minute against a mine resistance represented by a water gauge of from two to three inches. Very few well regulated mines give water gauges as high

as this, and according to the most rigid requirements of the present bituminous mining law of Pennsylvania, which calls for 150 cubic feet of air per minute for each and every person employed in the mine, such fans would provide for working forces ranging in number from 1,300 to 3,000. These numbers far exceed the requirements of any development of bituminous mines at present, and it will be readily seen that so far as the volume of air is concerned, the matter of ventilation is far in advance of any other department of bituminous mining. The ice accumulation can be obviated by properly constructed shaft rings, and the comfort of the comparatively small number of men at the shaft bottom should be no bar to the general safety of the mine.

The development of ventilating apparatus before mentioned has been brought about by the exudation of explosive gases from the coal. It has now become possible with these immense volumes of air to dissipate and carry off the gases, but these large bodies of air sweeping with great velocity through the air ways, have a tendency to take up the moisture with which the mines are normally charged and dry out the dust which is present wherever bituminous mining is carried on. This, under certain favorable conditions, becomes a more frightful menace than the explosive fire-damp which has kept the mining world in terror for many generations. The fire-damp very rarely explodes over the whole of the mine at one time; while a very slight explosion, which is either caused or augmented by dust, is extremely likely to follow from place to place, gathering force with its progress and penetrating every crevice of the mine, giving what is known abroad as a "Monster" explosion. The recent deadly explosion at the Harwick mine, where but one man out of 178 within the mine came out alive, is a striking example of the dangers attendant upon this class of explosions. The greater danger of dust as compared with fire-damp is shown in the following paragraph taken from the "Transaction of the Mining Institute of Scotland." being a portion of an exhaustive paper on explosions in coal mines, prepared by J. B. Atkinson:

"Mixtures of fire-damp and air are only capable of transmitting flame within certain limits. There must be from 5 to 20% by volume of fire-damp in the mixture. The case, with respect

to coal-dust and air does not appear to be parallel. One pound of coal dust and 160 cu. ft. of air are required for complete combustion. Assuming an air way to be 8 ft. x 5 ft. sectional area, and taking coal-dust to weigh twenty-six pounds per cu. ft., then for each 160 cu. ft. of air in such a road to be supplied with one pound of coal-dust, the surfaces of the road would require to be coated with a film of dust 1/228 inch thick. Such a quantity is far below what in practice is present on ordinary dusty roads, along many of which it has been observed that an explosion has passed with great force. These roads would, at the time of the explosion, have suspended in the air a quantity of dust in excess of one pound to 160 cubic feet of air, and in no case where the dust was pure has the writer seen any evidence that the passage of the explosion has been checked by an excess of dust. It seems that in a coal-dust explosion a minimum quantity of dust must be present, which is probably much greater that the quantity named as being required for perfect combustion, but practically no maximum. If this be true, it has an important bearing on the question. The minimum quality of coal-dust occurs constantly over long lengths of roads in mines, and consequently the conditions are present for propagation of a coal-dust explosion. This is to say, many roads in mines, in their normal condition, contain the necessary agents for an explosion of coal-dust and air, while a similar state of things, due to the presence of fire-damp and air, is an abnormal condition."

It has been variously attempted to avoid this danger, both by sprinkling in dusty localities and by attempting to saturate the incoming air with moisture. There is in this one particular, a broad field for investigation as to feasible and efficient methods of meeting this danger. A promising suggestion has been made and acted on, to a limited extent, in a few localities—this being to take advantage of the powerful fans, at a time when the mine is idle, to turn the full force of the air current in the various splits, taking them one at a time, and thus withdrawing from the mine the dangerous dust. It has been stated that German experiments show that the dust which will remain quiescent in the presence of a current of air traveling at a rate of forty miles per hour harbors no danger as an explosive. If this is proven correct, it

will be a simple matter to modify the designs of our fans, increasing the diameter and decreasing the width, thus materially aiding in the solution of the dust problem without making any addition to a cost of production which is already heavy.

The distinction which is now made by the mining laws between gaseous and non-gaseous mines should, in the opinion of the writer, be abolished. There are, no doubt, mines which never have, nor ever will, generate explosives gases in "sufficient quantities to be detected by the ordinary safety lamp," but it will either be a bold man, or one who has some financial interest at stake, who will undertake to state definitely that any particular mine belongs in this class. The dangers attendant upon coal mining would be reduced to a minimum, if every operation were conducted in the same careful manner as is absolutely necessary in a large majority of the mines in operation. Certainly no one will attempt to gainsay the benefits arising from such careful methods of operation—benefits which will be shared alike by every miner and every official. One of the first steps in this direction should be the prohibition of all open lights and the substitution of a safety lamp which cannot be opened without special appliances. Strong prejudice exists among miners, who have had any experience with open lights, against safety lamps on account of the weight, inconvenience and the inferior quality of the light. None of these disadvantages would seem incurable in the light of what has already been accomplished by human ingenuity.

Many of our disastrous explosions have been directly chargeable to the explosives used in blasting down the coal—either by reason of their inflammable nature, or by imperfect shots blowing out and igniting gas or dust, or by both in conjunction. Many are ready to proclaim that no such thing as a flameless explosive exists, and many others are equally certain that some classes of explosives carry with them no danger in this particular. But there is no doubt that many exhaustive experiments made abroad during the last ten or twelve years show that this danger may be almost, if not completely nullified. It seems imperative, however, that the actual use of the explosives should be taken out of the hands of the common miner and left with skilled men who make a specialty of this class of work.

Rule 15 of the Pennsylvania Mining Act of 1893 states that, "When places are liable to generate sudden volumes of fire-damp, or where locked safety lamps are used, no miner shall be allowed to fire shots, except under the supervision, and with the consent, of the mine foreman, or his assistant, or other competent person designated by the mine foreman for that purpose." This rule is usually interpreted by appointing a man, who is designated as the "shot-firer," and who is expected to make an examination for gas, and when none is present, to fire the shot. This provision is not comprehensive enough, as it leaves one of the most dangerous features of the shooting, i. e., the drilling and the loading of the hole in the hands of the man who may be skillful, but is far more likely to be ignorant of what is actually required.

One of the positions of great responsibility in mines is held by the fire boss. Upon him devolves the duty of the examination of the mining places and the decision as to whether they are in a safe and fit condition for the entrance of the men. His duties as defined by the Act of 1893 of Pennsylvania, are comprised in the following:

"In all mines wherein explosive gas has been generated, within the period of six months next preceding the passage of this Act, and also, in all mines where fire-damp shall be generated after the passage of this Act, in sufficient quantities to be detected by the ordinary safety lamp, every working place, without exception, and all roadways shall be carefuly examined immediately before each shift, by a competent person, or persons, appointed by the superintendent or mine foreman for that purpose. The person or persons making such examination shall have received a foreboss certificate of competency, required by this Act, and shall use no light other than that enclosed in a safety lamp while making the said examination. In all cases said examination shall be begun within three hours prior to the appointed time of each shift commencing work, and it shall be the duty of said fire boss, at each examination, to leave at the face and side of every place so examined some evidence of his presence. And he shall, also, at each examination, inspect the entrance or entrances to the worked-out or abandoned parts, which are adjacent to the roadways and working places to the mine,

where fire-damp is likely to accumulate and where danger is found to exist, he shall place a danger signal at the entrance or entrances to such places, which shall be sufficient warning to persons not to enter said places."

As the law now stands, it is possible to so interpret it, that the actual working places may receive no other visit than this one preceding each shift. If open lights are used, it is, of course, a necessity that each working place should be examined before it is entered by workmen, but if no other lights except safety lamps were present in the mine, this visit of the fire boss might be more profitably made at another time than just before the men begin work. So far as gas is concerned the working type of safety lamp, by going out, would immediately notify the miner of its presence. So far as the other dangers are concerned, they might with safety be left temporarily to the judgment of the miner himself.

The critical period of the working shift is just before the firing of the shot, and this is the time at which the fire boss should make his inspection and leave the record of his visit. His morning inspection, then, instead of being a hurried chase from one room to another, should be a leisurely inspection of the ventilation, beginning with the fan and ending with the return airway, and should include a daily measurement and record of the quantity of air traversing the mine, instead of the weekly one now required by law. This examination, too, should cover the entrances to worked-out and abandoned portions of the mine, the same as is included in his present duties.

The provisions of the Act of 1893 of Pennsylvania with reference to the employment of State mine inspectors are admirable, and their employment has been of great and lasting benefit to the mining industry of this State. The weakness of the law, however, is the extreme difficulty of performing all the duties it requires, and at the same time give each individual mine the attention necessary to carry out the letter and spirit of the law. The inspection districts are required to have not less than 60, nor more than 80 mines in charge of each inspector, and each mine is to be visited not less than once in every three months. In addition to these periodic visits, the mine inspector is required to

make additional visits in the case of fatal accidents. He is, also, required to make a yearly report, which is of necessity voluminous in character and whose preparation requires a considerable expenditure of time. It is difficult to fulfill the spirit of the law without making the set visits to the mines at such times as they are engaged in actual operation. Assuming that an inspector has under his charge 70 mines, four visits a year to each of these mines require 280 days, as it is rarely possible to visit more than one mine in a day. Thus the entire working year is accounted for with no provision for the irregular visits which are emergency ones, and must be made regardless of the regular visits; besides very few mines are running 280 days in one year—200 days per year would be more nearly the average. The impracticability of making these visits at the time when they should be made, i. e., when the mine is in operation, is readily apparent.

There are at the mines, two officials other than the mine inspector, who requires a States license, but receive their compensation from the owners of the mine. While their duties are strictly defined by law as those of the mine inspector, it is only natural that they should depend largely on the mine inspector, who receives his compensation from the State. The existing condition of affairs would be improved if the mine inspector received reports at stated intervals—say weekly—giving in detail the condition of the mine with reference to the carrying out of the provisions of the mine law. These could properly be signed by the mine foreman and the superintendent, thereby throwing the whole of the responsibility on the resident officials. At the same time the mine inspector would have a far more intelligent grasp of the situation as it existed in his district, and could select the mines to which he should devote his attention. Even this suggestion is predicated on a very material reduction in the number of mines under each inspector's charge, as there is no scheme of procedure that would make it possible to adequately inspect as many as sixty mines over districts of such wide extent as exist in this country.

A feature of this law which caused heated discussion at the time it was formulated, was the discretionary power granted to the mine inspector. It would seem possible at the present time, with the additional experience of the last ten years, to make a

new law comprehensive enough that but little would need to be left to the discretion of the mine inspector. At the present time the only redress that exists in the case of an objectionable decision on the part of the mine inspector is an appeal to the county courts in the county in which the mine is located. The court is empowered to appoint three competent and disinterested persons to make an examination of the facts in question and the findings of this board are final, unless exceptions are taken, in which case the whole matter is passed upon by the court. If the decision of the mine inspector is finally sustained, the costs of the proceedings fall upon the people who object to this decision; if it is not sustained, the costs are paid by the county. This could be much simplified by making the first step in cases of this kind an appeal to the Chief of the Board of Mine Inspectors, whose decisions would be recorded and eventually become an interpretation of the law. In case of objections to his decisions, they could be tested before the proper courts. The effect of this would be that the district inspector would be more ready to make decisions, and the operators more ready to object to them, and the interpretation of the mine law thus be made more nearly uinform. A precedent for this exists in connection with the school law of Pennsylvania, which is amplified and made clearer by the recorded decisions of the various superintendents of public instruction.

One of the accompaniments of our present industrial system is the necessity for employing large numbers of foreign laborers. This carries with it great inconvenience on account of the difference in language, and is fraught with danger in many industries, and especially so in the mining industry. Whatever may be the objections, it is an undoubted fact that it would be useless to attempt to carry on mining without the help of this much condemned body of laborers. The difficulties in the way of properly instructing this body of men are many. The Act of 1893 of Pennsylvania provides that the general rules of the mine law shall be posted in a conspicuous place, and shall be printed in every language which is used by any ten persons working in the mine. This is a recognition of the difficulty, but is not an adequate solution of it. In the first place, many of these people are unable to read the rules even in their own language. The fact that they are posted up

conspicuously is, also, no guarantee that they are being read and understood. I am at a loss to say exactly what should be done in this connection, and am not certain that it would be feasible to require them to pass an examination on the principal provisions of the mine law. At the same time I am convinced that the employment of these ignorant people without any further provisions than those which exist at the present time, carries with it so much danger that something should be done, even to the extent of employing interpreters at each mine for the purpose of giving necessary instructions. It is entirely possible, however, that a trial of this might show that an interpreter could be stationed at some central point and give class instructions which would make it possible for these men to be employed with safety to themselves and the other employes of the mine.

No matter how strong the sentiment may be in favor of the obedience of law, there will always be some violations. These violations should be more easily punishable than is now the case in Pennsylvania. This State requires a conviction before the Court of Quarter Sessions, and provides a penalty of a fine not exceeding $500 or imprisonment in jail for a period not exceeding six months, or both, at the discretion of the court. Many of a county court. To bring such matters before the court, too, of the violations of the law seem too trifling to have the attenion of a couny court. To bring such matters before the court, too, is a matter of considerable trouble, and the effect has been that it has been left to the mine inspector to bring the offenders to book. His personal observation is of necessity much limited, and the proper person to do this is the mine foreman in charge of the mine. If it were possible to have such offenders brought before a justice of the peace, the matter would be much simplified. The comparatively insignificant violations of the law would then receive the proper attention, and the discipline of the mines would be very largely improved; in many cases the mere payment of the costs of the trial before a justice would be a sufficient bar to any further violations; and there is no doubt that if the smaller matters were carefully followed up, far less trouble would be experienced with the greater and more serious violation of the law.

It was originally intended that this paper should cover some

important points of practice in mining that were either being neglected or glossed over. A great many of these, however, had been anticipated by the Act of 1893 of Pennsylvania, and it seemed wise to take this Act for a text. The difficulty of this Act is, that many of its provisions are merely suggestive, when they should be comprehensive and explicit. This is notably the case with reference to its provisions concerning dust, the only allusion to which is found in rule 60, which states that, "In mines where coal dust has accumulated to a dangerous extent care should be exercised to prevent said dust from floating in the atmosphere by sprinkling it with water, or otherwise, as far as practicable." This leaves one of the most dangerous features attendant upon mining with practically no provisions for its care.

The good that the law has accomplished, even in its present form, has been so marked that it would seem reasonable that its usefulness could be very much broadened by making it the exponent of all the knowledge now available with reference to the safe and successful operation of mines. It has been the writer's experience, too, that there is a widespread sentiment in favor of the observance of the law, but numerous interpretations of the same thing exist, and stress is laid on particular points by some and on different points by others. The law should in itself be a complete manual of instruction on the art of mining. Its provisions should be clearly and accurately defined and its penalties easily imposed. Careful consideration shows a striking similarity of conditions in all bituminous mines and calls for a uniformity in the laws which are framed to govern these conditions, and it is with the desire to give an impulse to some such movement that this paper has been prepared.

DISCUSSION.

Mr. Flanagan—Gentlemen, we have listened to a paper that is not only interesting, but it goes back to the beginning, at least the subject of coal mining does. We all realize how much the engineering profession and all the mechanical work of the world is dependent on the coal supply, and naturally anything that relates to the production of coal is interesting to a body of engineers, whether they are mining engineers, or mechanical, or

electrical, or any one of the three hundred and odd classes of engineers that one of our members discovered at the banquet one evening. This paper you will notice deals very largely with the necessity for legislative enactments regarding the safety of mining operations. It is not necessary to say that without the assistance of the engineers the legislators would be very helpless. The legislator can only embody, in the form of law, safeguards which the engineers have devised and found to be available for the purpose. I don't know how many of the members are as ignorant of the whole subject of coal mining as myself, but I think a great many of us will be surprised to learn that there is anything more dangerous than fire-damp. The author of the paper of the evening points out a still more dangerous substance than the much-dreaded fire-damp. I have no doubt there are members in the audience to-night who can throw still further light on the subject, and as I am outside of the mining industry entirely, I will make room for those who know more about it, and I hope the discussion will be lively and extensive. I think Mr. Schluederberg could give an interesting talk on the subject before us.

MR. SCHLUEDERBERG—I think, Mr. Chairman, that the paper just read was carefully prepared. It is on a subject that will be taken up by our law-makers in the near future, and when taken up, I trust will be handled in a fair and intelligent manner. Our law-makers, in treating this question, will certainly need the assistance of the engineers and others who are familiar with mining, so that the very best results may be obtained.

This is a large, broad question, on which there are many different opinions that will have to be harmonized. We can pass laws, but we cannot pass the laws that will make people perfect, and, as the writer of the paper well says, we have an excellent mining law, but with the people we have had to deal with in the business, it has been a difficult and almost impossible task to carry out fully the provisions of the law as they should have been carried out, and the result has been more or less trouble, accidents and loss of life.

I do not think, however, that the coal business, with its present magnitude and conditions has been more dangerous or

destructive of life and property than has been the case in other lines of industry. We seem to hear more of troubles and accidents in and about coal mines than we do of the troubles and accidents in shops and mills. There is, however, always room for improvement, and anything that can be done to improve conditions and lessen danger in mining should be done.

MR. SCHELLENBERG—By courtesy of Mr. Fohl I read his paper yesterday and have put down something. I am more indebted to him because I disagree with him. I agree that there are other causes greater than the fire-damp for deaths in the mine; there has been an increase of deaths from falls. There used to be about 40 per cent. deaths from falls, or perhaps it was accidents and deaths. The increase brings the percentage above 50. And it is the methods of mining that are at fault, I think. People are greedy to mine the coal by machinery and let the rest go. This is what I have written:

I may claim a lively interest in this subject from many years of experience. From earlier residence in the anthracite regions, I was prepared to side with the miners' demand for State inspection in the bituminous regions also, and I had the peculiar experience then—thirty years ago—of being alone among officers and operators here; they were all in opposition to what appeared to them an uncalled for interference with private business. Twelve years later I was a member of the commission that revised the law and changed its title to provide *for the lives, health, safety, and welfare of the persons employed.* And I helped to make the draft of the present law of 1893.

I am never astonished any more to see the pendulum swing to opposite extremes and therefore am not surprised in this case to hear the call for too much law.

I do not consider uniformity over the State lines practicable as legislation even if advisable in some respects for the contiguous territory; we have two laws in Pennsylvania and their revisions are independent of each other; only in having one Chief Inspector for the State are the bituminous regions common with the anthracite.

I like to argue that the provisions for the gaseous mines, so-called, make for the health and welfare of the men that have

to be in them, to a degree in advance of conditions allowed where black-damp generates in excess.

Fire-damp in mines is a blessing in disguise; for there then ventilation has to be good; better than in assembly rooms generally—than in crowded churches or court rooms, for instance. We here regard fire-damp, as natural gas, under control piped into our houses for fuel, as a blessing, and our only fear about it is that the supply may fail. We have learned that it requires ten volumes of air mixed with one of gas for perfect combustion and may know that this is in a mine the diffusion for greatest explosive force; fifteen volumes of air and five volumes of air are the extremes of combustibility for one volume of gas. All our progress is predicated on the control of violent deadly agents. We deal with fire at forced intensity in smelting, and in generating power we get motor fluids that are hellish if they break away. Even our travel must be at a forced pace to give pleasure. We analyze that we are refined as we feel able lightly to guide dangerous elements.

I continue to favor the rule in the mining law that reads: "No safety lamps shall be intrusted to any person for use in mines until he has given satisfactory evidence to the mine foreman that he understands the proper use thereof and the danger of tampering with the same." I think it intolerable to have a producing coal mine here under conditions forbidding the use of open lights in the hands of the ordinary workmen; for these the atmosphere must be measurably free of noxious admixture that they may labor in wholesome air and light. And we should all know the required use of the safety lamp in miners' hands to be in the lead of the air current, in cutting narrow entries for all uses next the solid around the working places proper, or in the initial breaking of the roof for retreating work. We should choose to exhaust all the coal, closing up what otherwise would be open space for magazines of lurking gas, and presently uncontrollable settlement over the wasting ribs of coal and expanding, endanger by squeeze the adjacent working places and passage ways. We have no mining yet where the coal cannot systematically be early exhausted in detail, to have controlled breaks to the surface in quiet settlement of the overburden and upward escape of its gases.

I would say haul out the extra dust—it is fuel of some use. A mine inspector does not want to be merely perfunctory, neither does he want too much discretionary power, naturally he does not crave extra responsibility.

I do not think he wants to direct methods of mining, although we would like him to write on the subject, in the fullness of his time. As for his hauling small offenders at the mines before justices of the peace, I believe his supervision not close enough for that; he is to see that the law is obeyed and his instructions and attention to the acts of the officers at the works, shown him by results. He should keep close enough account of all ways in the proportion of their importance, so that justice may extend from the heads to the hands at a colliery.

Mr. Schluederberg—Mr. Chairman, I did not have the advantage of our friend, Mr. Schellenberg, of seeing the paper beforehand, and am, therefore, not so well prepared to discuss it.

Whilst I believe that people cannot always be made to do right by the passing of laws, yet there should be a way of reaching them in this case. There is no question that there has been a great deal of uncalled-for waste in one of the greatest of Pittsburg's products. There is nowhere to be found any finer coal than in the Pittsburg vein, but, for various reasons, the coal has been mined in a wasteful manner in the past; people wanted a cheap coal and mined only what was removable by machines and did not go to the cost and expense of mining the remainder by hand, cleaning up and taking down the roof or surface, as should have been done in any well-regulated mine. It is a criminal waste to leave coal in this way, because it is a loss that cannot be replaced.

There should, therefore, be some means, laws or otherwise, by which coal mining could be done in a proper, safe and systematic manner. How this is to be done remains for future consideration. I am not quite clear or decided in my own mind at present.

Mr. Flanagan—I don't think I could make it clear, either. But I would like to ask Mr. Schluederberg if he thinks that the price of coal has much effect on the question of whether the mine owners would clean it out or not. Even if the people are

willing to pay higher prices for coal, while the mine owners find it cheaper to mine with machines, and leave part of the coal in the earth, they will not cease to do that, unless the provision in the last part of his remarks are put in force and there is some measure of weight brought to bear on them. Will they mine their coal out in detail even if the price of coal is higher?

MR. SCHLUEDERBERG—I am not much of believer in too much supervision, but there will have to be something done to make these people do this. The selling price has had much to do with it, but it is all wrong. This thing of selling an article at a price and then expecting the producer to produce it low enough to make a profit at that price is treating it from the wrong end. The coal should be produced just as economically and cheaply as possible and then sold at a profit and the selling price should have nothing to do with the manner of producing. Because it is cheap, that is no reason why the mine should be left in bad condition. It does not pay in the end. The man that does that sort of producing coal cheap, is simply breeding trouble for those that come after him. If it is necessary for the State to step in and supervise this, let the State do so. Here should not be any waste.

MR. FLANAGAN—I would like to ask a question in this regard. When the coal is taken out, what becomes of the space that it is taken from? That is when you mine all the coal out.

MR. SCHLUEDERBERG—Well, if it is properly mined, systematically, the overlying strata, the roof, is supposed to break and sink. It does not always do that, but it can be brought down in such a way that the spaces will be fairly well closed and not stand as reservoirs of bad air and gases.

MR. FLANAGAN—Does that usually break down without affecting the surface of the ground?

MR. SCHLUEDERBERG—Depending largely on the depth. It may come to the surface or it may not.

MR. FLANAGAN—Mr. Fohl, has the discussion brought out any points that you could throw further light on?

MR. FOHL—The suggestion regarding the exhaustion of coal. Of course, I had not touched on that at all. I am glad to see that brought out and I agree with Mr. Schluederberg that

it is a very important part of the mining methods and deserves equal attention with anything I have spoken of in the paper. Whether the law should regulate that I am not prepared to say, but there ought to be some compulsion in the matter so that everybody would mine the coal properly. I think that would be perfectly in line with the other suggestions that have been made.

MR. FLANAGAN—Are there any other gentlemen that have something of interest to tell us? I had no notion that I would be called on to preside at the meeting to-night, and it may be there is someone else here as well prepared as Mr. Schellenberg was. Until he arose to his feet, I did not know that he would have anything other than the usual discussion to offer. If there is anyone else that can throw any light on the subject, we would be glad to hear from them. Mr. Diescher is interested in mining properties, not in coal, but he can speak a word perhaps.

MR. DIESCHER—Not in coal mining. I would like to ask Mr. Fohl how it is that the mines are only operated 200 days a year, or about 200?

MR. FOHL—I think possibly Mr. Schluederberg could answer that better than I can; but I will hazard an answer and say it is because there is no demand for the coal during portions of the year and because of the scarcity of cars. There are half and quarter days that you cannot run. Taking it altogether, I think in this district it will amount to about what I said, 200 days per year.

MR CRONEMEYER—Mr. Chairman, I would like to ask a question which perhaps has no direct bearing on the subject but may be of interest. What is the nature of this dust? Is it a very fine dust or a coarse dust? If the dust explodes so rapidly under conditions where it is not wanted it might be of interest to know just under what conditions it does produce these explosions so we might put these explosions to some practical purpose. We take a whole lot of trouble in taking gas from the coal to produce explosions to serve in gas furnaces, and I understand a good many experiments have already been made by crushing coal and burning it in furnaces under boilers and other appliances. Now if we knew something about the condition of

coal in the mines it might give us a clue as to how we are to prepare our coal when we want the explosions.

MR. FOHL—I touched lightly on that in the paper. The Germans say that the dust which remains unmoved by a 40-mile gale is not explosive. If carried further, that would go to show that the coarse dust is not the explosive dust. It is the minute particles of the coal that make the danger and those of course are very light and if they can be driven out the heavier particles have no explosive qualities. It is the very finest particles of the coal that give the danger. In many cases I believe that it is the minute spores of the plants from which the coal was formed originally that cause the most danger. It is apparently the vegetable remains that give the trouble.

MR. STUPAKOFF—I would like to ask if most of the combustible materials that can be deposited in dust are not explosive? He has come down to a question of vegetable organism from what he supposes are the explosive elements of coal dust. Won't you find the same elements in flour mills? Isn't the same element there, not necessarily coal dust, but most any kind of dust that is formed?

MR. FOHL—That is notably the case. There have been explosions of the same character in flour mills as we have in coal mines. And I believe mineral dust will also at least propagate an explosion. Any kind of dust will assist an explosion and coal dust will in many cases originate it.

MR. ALBREE—I would like to ask a question about that dust. I had always understood that the dust causing explosions, either in a flour mill, coal mine, or anywhere, was due to the dust suspended in the air. That it made the action of the explosive mixture. From what you say I judge the dust is on the floor and it is only in the case of an explosion of some other sort, starting a current of air rushing through the mine, causing this dust on the floor to get into the air, that carries the explosion through the various entries of the mine. That is, it is not the dust in the air, but the dust in the ground, that is suddenly started up. Now, what is the original explosion, a fire-damp explosion, or a dust explosion, or what?

MR. FOHL—It is the dust that is in suspension in the air that

is explosive. And the dust from the sides and the floor of the mine is usually started up by some other agency, usually a blown out shot which creates a disturbance and starts up clouds of dust and the dust suspended in the air propagates the explosion.

MR. DIESCHER—Isn't it as a rule, in the case of an explosion of that kind that there is heat, that it is necessary to have some heat produced to start an explosion? Would the coal, even if it is over a much larger area and the air in greater contact to the carbon, could it explode unless you would add heat to it?

MR. FOHL—That is true.

MR. SCHELLENBERG—That is only a propagation of what is initiated by the explosion of the gas. Those views I think are established, and the figures Mr. Fohl gives there of a pound of dust to 160 feet air, you will recognize as that 13 to 1 by weight which carbon requires for combustion. You know we say roughly, it takes twelve tons of wind to make one ton of iron.

MR. FLANAGAN—Any further remarks pertaining to the subject? I would like to ask a question of what percentage of coal is left in the mines by the machine-mining methods which have been condemned to-night. I might ask Mr. Schluederberg that question directly.

MR. SCHLUEDERBERG—In a well regulated mine they take out 80 per cent. of the coal, about 80 per cent., with the machine.

PRESIDENT—It seems like leaving a large percentage of a valuable commodity there.

MR. FOHL—In many of the older mines that Mr. Schluederberg touched on a little while ago, the percentage remaining in the ground has been as high as 40 per cent. in the past.

MR. SCHLUEDERBERG—I am speaking of the present.

MR. FLANAGAN—Well what would finally become of that 20 per cent. under present conditions?

MR. SCHLUEDERBERG—The 20 per cent. or as much of it as can be, say 15 per cent., should be taken out with a pick at once.

MR. FLANAGAN—They do finally go back after it then?

MR. SCHLUEDERBERG—That is done now where the mining is properly done.

MR. FLANAGAN—And where it is not done, do they expect to do it at a subsequent date?

MR. SCHLUEDERBERG—No, I think not. They simply drove up rooms with machines, leaving the ribs all, or in part, standing and the result was an opening or standing reservoir for bad air and gas, and the roof left hanging in a dangerous condition, likely to bring trouble sooner or later to other parts of the mine.

MR. FLANAGAN—Any further questions? If none of the members will ask any I will ask another, that is, what is the character of the small violations of the mining laws which have been referred to in the paper and once or twice in the discussion?

MR. FOHL—I might state that one of those would be the sort of oil that is burned in the lamps. There is a certain quality of oil specified by the law. In order to save money the miners are only too prone to buy a cheaper quality and thus vitiate the mine atmosphere. That seems rather trifling in itself but every now and then it is necessary to "jack up" five or six people in order to get that stopped. Were it possible for a mine foreman to take the first offender out before a justice of peace and have a fine imposed, that would probably stop this trouble at that mine. There are numerous others of the same character.

MR. KLINDWORTH—While you are speaking of safety-lamps, I would like to ask the question of the size of the opening in the gauze or whatever you call it?

MR. FOHL—I think we will put that up to Mr. Schellenberg.

MR. SCHELLENBERG—The Davy lamp had 28 to the lineal inch. That makes twenty-eight square (784) for the number of meshes in the square inch.

MR. FLANAGAN—It appears that our safety lamps are an open line also. I think some of the members would be interested in a little general discussion of the methods of mining. What constitutes the call in one case for a safety lamp and in another case for an open lamp? Mr. Schellenberg referred to that somewhat in his paper, but I, for one, am not clear upon the subject as yet.

MR. SCHELLENBERG—I might make a diagram of it. The going ahead into the solid relieves the gas, of course, that is

stored, especially if that be against the dip, that is, if the coal falls away under water. It is from that source the gas will exude. Now then, the driving ahead into the coal seam to make advance opening requires the use of a safety lamp, especially where it is against the deep. Were the work laid out in panels, in which the rooms are sub-divisions, there would be given a space of air all around. Now, I submit that within that space the mining and ordinary laboring work is simply work with open lights, until it comes to drawing the ribs. The starting on the ribs to make the first break, especially in the eastern part of the regions, brings down some gas, and there safety lamps may be used again. After an air current is established anywhere here, safety lamps are a nuisance. They don't give light enough for the men to take care of themselves with them as safely, and they ought only to be in the hands of real miners under conditions where they are required. About the foreign languages: any sort of man can be in these panels, you know, after these are ventilated. There they can be left simply to hew away. Up in the coke region, of course, it is only digging they do, they don't even undermine there, and there, by the way, they get their gas from the roof altogether after rock is made to break; while here the gas comes out of the face of the seam proper, and after the place is cut past a cleavaged joint it ceases to come, as it comes only from the solid. It does not generate in the open work, but by admixture places there inflammable air. It is quite the reverse in these spaces, where the generation of black damp (carbonic acid) slowly proceeds and the open space is not ventilated for working in. Fire cannot burn there. The mine ought to be closed up just as before it was opened up. There ought to be only working space to ventilate. The ventilation should be carried around the parts that are alive, that are moving. The rest to be dead, laid off, and not wanted. I always say that the breaking of a roof should proceed to the surface of the ground, and there is no reason why that can't be done, and a settlement of the ground made in detail under control, so that there will be no more trouble in the place. That is, mine out the coal, take away all of it, as Mr. Schluederberg says, up to 95 per cent. You should get the coal out, but you can't get all of it out with machine, a part of

it has to be taken out by hand. But it ought to all go out, systematically and regularly, because that part that is standing transfers the strains on it from the overburden to the open part, and such movement of the strata brings in danger of letting in gas again, besides involving the loss by crush of the broken remnants of coal of the open spaces. The controlled settlement of roof alongside of workings obviates that loss. It would be easier to explain if you were all at a coal mine to see.

MR. FOHL—I would like to submit the fact that with reference to the closed lights it is claimed that the experiments made abroad show that coal dust can be exploded by being brought in contact with the open flame, and that is part of the reason for the idea of abolishing the open light altogether.

MR. SCHLUEDERBERG—Under the ideal conditions as presented by Mr. Schellenberg, conditions as they ought to be, the only question is how will they be brought about? The claim that the safety lamp is unnecessary, in fact a hindrance, I would like further explained by Mr. Schellenberg and to have him explain how the people can be made to do right as far as mining is concerned. Who is going to do it, the State?

MR. SCHELLENBERG—The things that you are not doing among you as citizens will bring us to a state of socialism. That, it seems, is coming from the top, while we have feared its coming from the lower strata. We are going into the state of socialism, the state to do everything and the individual to gradually lose his liberties, and it seems he don't deserve to keep them. It is very plain that if we have to see men wasting the resources right around that rightfully belong to posterity that the State must interfere. It is a bad business. A man must not think he has a right to do what he pleases with what he calls his own.

MR. SCHLUEDERBERG—He only thinks so, however. Would it not be perfectly right to have the State step in—in a case such as this? I don't quite agree with Mr. Schellenberg. I think there should be a supervision, and have the mines properly laid out. Many of them are not laid out looking to the safety of the lives to say nothing of the property. They should be properly laid out, and the coal should be properly mined. That I think can be done only by State supervision.

MR. SCHELLENBERG—Well, Mr. Fohl there is a Socialist, too, you see. He wants the mines laid out.

MR. FOHL—I firmly believe that a good deal of the trouble is due to ignorance on the part of the people who are in the business. But I also believe there is a strong tendency to do right. I think there are a whole lot of people who would be perfectly willing to do what they should if they were told what to do and my idea of the law is that it should be an instructive instrument rather than a compulsory one. And I don't see any way to bring the necessary information before the mining public in as good shape as can be done by the law, and I think further that the examination of the mine officials should be based on the law itself, and not on some theoretical knowledge that they must acquire from books.

MR. FLANAGAN—I think that it is well said that what we need largely is more knowledge, and that is the reason I said in the beginning that this is a subject that is interesting to engineers because they must find a way out of every difficulty as it comes up, and when it becomes necessary for the law to step in and see that that way is traveled and made use of, why that is neither Socialism nor paternalism. There are certain things that it is necessary for the State to do and that are properly State functions, and it is highly desirable that the State exercise every function that belongs to it. And everything that does not belong to it. We need to develop individuality among the people and idividual rights among individual businesses, but there are some things that are not individual business, although men are engaged in them and they call the property theirs. A railroad is not an individual business and the State has a right to regulate it in many ways. If you go back to the original charters, the charters are not granted to the railroad companies as merely giving them a property right in that stretch of ground and the right to operate trains over it; the charters read more that the railroad is a State servant, that for the time being, the State has found its best interest in delegating the necessary authority to a corporation to establish railroads and manage them; to go back to the first principles, when the State finds it advisable to take charge of the railroad itself,

it is theoretically in a position to do so; it has never surrendered the fee simple right which inheres in the government. The question of mining may be somewhat related to that of railroading in the same way, in the fact that the mines and miners are dealing with one of the natural resources of the country, where it may be necessary for the State to step in and conserve those resources if they are being very seriously sacrificed; and we have none of us reached the point at which we consider that the State in taking proper steps to preserve human life is oversteping its own authority. In callings that are managed by individuals we have granted the right of the State to step in and make certain regulations. If a man starts a machine shop and puts certain machinery to work, we have admitted the right of the State to step in and see that he shall put guards over his gearing and guards around the belts and certain other parts of the moving machinery. And if the State can interfere in a business that is so strongly an individual one, as the mere management of a machine shop, it certainly has more rights in one that partakes so much of a public nature as taking the coal, one of nature's resources, out of the earth and bringing it to the surface.

MR. STUPAKOFF—Mr. Chairman, I notice that you are drawing a comparison between railroads and coal mines. To illustrate a case, I don't know but what I might draw a further case from the railroads. An ordinary section boss down on the railroad knows what a good track is, but when he gets down to such a condition that he is not bossing more than two streaks of dust and a right of way, it is not his fault if there is a large loss of life. You have got to get down to the question of stocks and bonds. It may be the same case in the coal mines. If they would spend a few more dollars on the mines they might educate the miners a great deal more easily and more quickly.

MR. SCHELLENBERG—The accidents do not come about as supernatural, providential, or beyond human control.

MR. STUPAKOFF—They used to hide behind an old law in connection with railroads that where there was a rock fell down on the track they put it down as an act of divine providence. They didn't say anything to the man that might have looked up there, seen that rock, and had it removed.

MR. FLANAGAN—Well a fairly written mining law, which is up-to-date and is the productof engineers as well as of legislators might cover such ground as that and make it plain whether the owners were culpably negligent, or whether it was one of those accidents that were unavoidable under the kind of conditions that human beings have to accept. It might be possible to avoid a great many accidents if we could afford to put ten times as much labor and cost in our production as we are doing now. Mr. Fohl's idea is that the mining laws should be sensible enough to outline the proper methods. To that extent the law would apparently be justified in its existence.

MR. SCHELLENBERG—I want to say that Mr. Fohl asks too much, however, in making his law uniform. That can't be. There is too much variety, and the State lines make it impracticable. See what a difference there is between the anthracite region and this region.

MR. FOHL—I only ask to have it uniform in the case of the bituminous mines, though, and one of the reasons for that is that the people who don't care try to shave down the cost of production and thus bring on more dangers. In other words everybody ought to be on the same basis. The people who don't care should be made to do right by the law so that they have the same conditions in their mines as the people who are willing to do the proper thing. That is the principal idea in the uniformity of the law, to bring everybody up to the one standard. I might cite as an example that in the neighboring State of West Virginia, when compelled to hire a mine foreman they do not ask that he be certified at all. They can hire anybody that they choose. In Pennsylvania we are compelled by law to hire mine foremen with a certificate, and, of course, there is a certain value attached to that certificate and just so far as that value goes we are at a disadvantage with West Virginia in the cost of production. This is only cited as an example to show the hardships that may be imposed in competitive districts whose laws are not uniform.

MR. FLANAGAN—Can we hear anything further from the members? I would like to see the discussion drift back to the coal mining people away from those who, like myself, can only

speak in very general terms. Those who know the ins and outs of the business can throw the light on it.

MR. SCHELLENBERG—Well I would like to say a word in favor of such a company as Mr. Schluederberg represents. I have as a Democrat, rather been opposed to consolidations, except in the coal business! I saw the good effects of it long ago in the anthracite region. The coal operator or lessee was with shining exceptions by contrast, a miserable man, a bad man, I don't know what words to use. But the consolidation brought in a management more intelligent, and of course with adequate capital to make proper additions of ventilation, so that I have always advocated it and preached it as here in the mining interests. That is, I was in favor of consolidation to have other better conditions: sanitary conditions; safe conditions in the mine and a conservation of this valuable fuel, the taking out of it systematically and safely, and not the cut-throat business and waste of the store in the ground. The bygone boss man here didn't know how to weigh coal even.

MR. FLANAGAN—Which way did he weigh it? For or against the buyer?

MR. SCHELLENBERG—Well, there is an anecdote of one of them that was called into the customer's office: it was pointed out to him that he was delivering only eighteen hundred pounds to the ton and he expressed great surprise, saying, "Is it weight you want. I thought you wanted cheap coal!"

MR. SCHLUEDERBERG—There is not any question but what in the last few years there have been great strides made in advanced methods and workings carrying out modern ideas in the coal business, far more so under the large companies or combinations than it was under the individuals. The business has enlarged, and has grown more dangerous by reason of deeper workings into the hills. In the early days when the coal was mined in the front of the hills, it was easy. They did not seem to need air nor trouble about drainage. But they have mines now where proper air must be furnished and the working places of the miners must also be kept dry. The dangers have increased by reason of the advanced workings and they have also increased by reason of the greater numbers employed, and in getting these

greater men were taken that were not practical miners, and the result was more accidents, but not as many now as formerly. They are growing less. The introduction of mining machines also caused much trouble. The men were ignorant of the machines, and in their efforts to hurry and make large earnings, they would not properly place the machines. Now we are getting over much of that, and I am quite sure the accidents are not as numerous and will grow less as we go along.

MR. KLINDWORTH—I move that we tender a vote of thanks to Mr. Fohl for his excellent paper.

MR. ALBREE—I want to second that motion and in seconding it I want to state that I particularly admire the paper for its clear and logical representation of the subject and that without any bitterness against the officials, miners or the workmen, but it was an extremely fair statement to engineers who are not familiar with the business and one that was so clear and concise that I for one have a very much better idea of that mining law than I ever had before. I wish to second that motion.

MR. FLANAGAN—I will be very glad to put the motion. I think we have all profited some by the paper in discussion.

Motion seconded and carried.

C. W. RIDINGER, *Secretary.*

INERTIA IN GAS AND STEAM ENGINES.*

BY A. T. KASLEY.

Most people have a very vague conception of inertia. It is something that cannot be seen, and when felt is nearly always in company with friction and other forces, so that it is difficult to properly realize its amount. Moreover, there is no well-known instrument for showing it, as we have the Bourdon gauge for steam pressure and the thermometer for temperatures. There is an instrument for attaching to a reciprocating engine which takes an inertia card somewhat resembling an indicator card, but I don't suppose more than one person in ten thousand has ever heard of it.

Fortunately, however, inertia follows two very simple mathematical laws, so that if we once get these laws clearly fixed in our minds we will be able to solve any problem that may come before us. These laws are:

Force=Mass×Acceleration.

Action=Reaction and is in the contrary direction.

We might state these laws in another form better suited to our purpose.

Inertia $= \frac{\text{Weight x Acceleration}}{32.2}$ in which acceleration is the change in velocity that takes place in one second. (The velocity, of course, is in feet per second.)

Inertia is equal to and opposite to the resultant of all the other forces acting on a body.

Let us consider, first, the simplest problem in inertia, viz., the falling body.

We are all more or less familiar with it. Applying the laws just enunciated, we have that the inertia equals the weight (the only other force) and acts in the opposite direction to gravity. Also the Acceleration$= \frac{\text{weight}}{32.2}$ Hence if we plot a curve with time as absissae and acceleration as ordinates we have the line AB,

*Read before the Mechanical Section of the Engineers' Society of Western Pennsylvania, June 7, 1904.

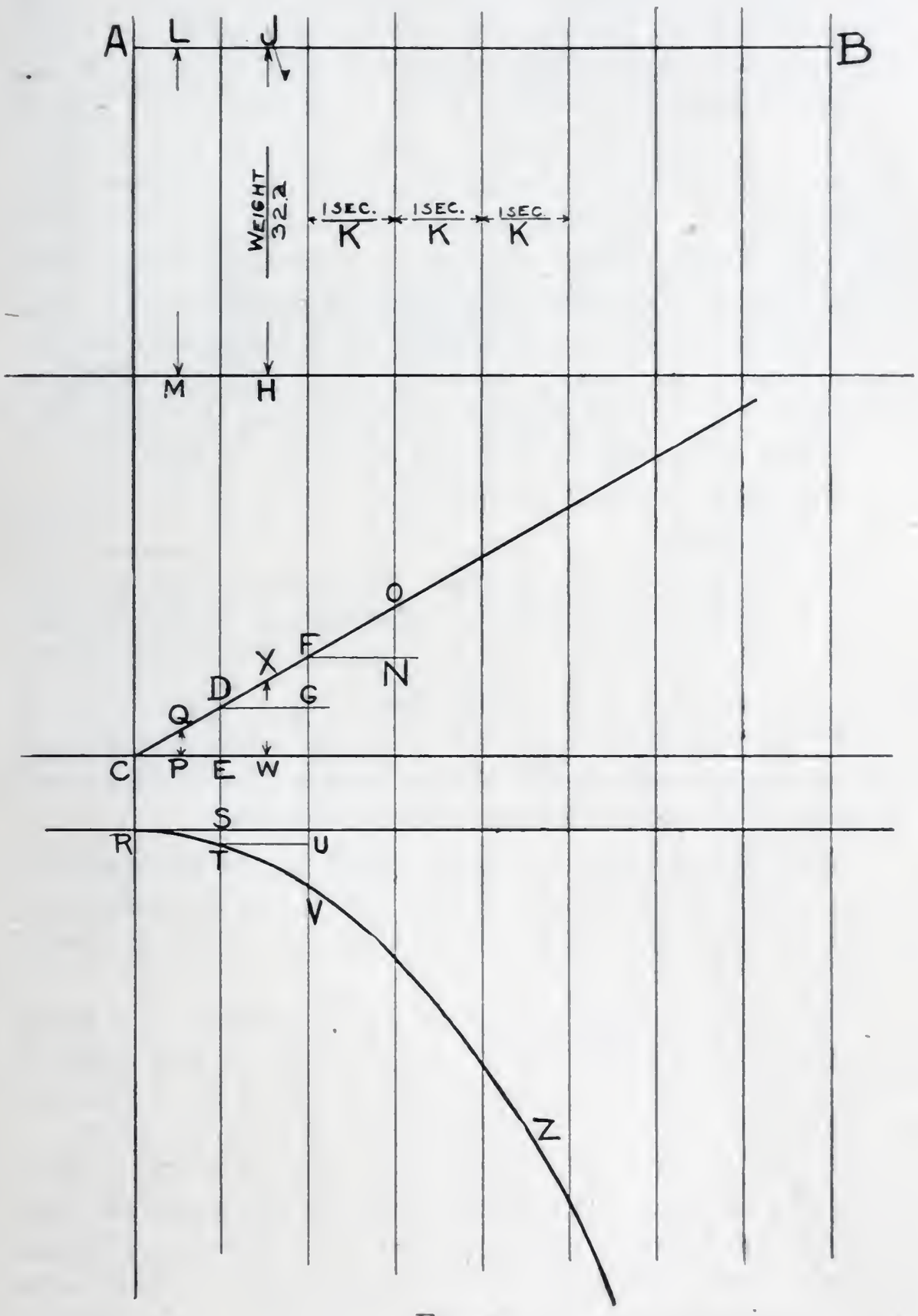


FIG. 1.

Fig. 1, which is horizontal in this case since the ordinate is constant. If now we prolong the vertical lines which are drawn equidistant and close enough together to give accuracy, we can plot the corresponding velocity curve. Starting at "C" with O velocity, i. e., when the body has just started to fall, we know that the mean acceleration during the time CE is the distance M.L. on the curve AB. But acceleration is the change in velocity which takes place in one second, and in $\frac{1}{K}$ second the change would be $\frac{ML}{K}$=DE. In the same way $\frac{HJ}{K}$ =FG, and if we set a pair of proportional dividers in the ratio K we can easily plot the successive rises in the velocity curve DE, FG, NO, etc., giving us the points D, F, O and through which we draw the smooth line C.O., which is the velocity curve, in this case a straight line.

Prolonging the verticals still farther we proceed to plot the curve of position.

Starting at "R," with the body at O distance from the hand, we see by looking above that the mean velocity in the time R.S. is P.Q., and since R.S. is $\frac{1}{K}$ of a second, ST must equal PQ feet per second X $\frac{1}{K}$ sec. = $\frac{PQ}{K}$ feet. Same way UV = $\frac{WX}{K}$ and our proportional dividers with the same setting as before enable us to easily and quickly plot the curves RZ, which you will recognize as the path of a stone thrown horizontally.

In figure 2 we have a problem which is just the reverse of this. Instead of having the inertia known and the position required, we have the position at any time located and the inertia required.

The crank A rotates uniformly, having attached to it by the connecting rod B a cross head C, piston rod D and piston E. What is the inertia due to the masses C, D and E. Laying out the crank pin circle into equal parts each moved through in second, and corresponding points on the line of motion of E by means of a tram, we can plot the curves FMKL where any ordinate HK is the distance of the piston E from the head end at that particular time. Then the piston having moved from C to M in $\frac{1}{K}$ second, its mean velocity must be MG feet $\div$ $\frac{1}{K}$ =MG$\times$ K feet per second = PQ.

The use of proportional dividers set ratio K enables us to

plot the points PV, etc., half way between the verticals and a curve through them is the velocity curve. Then, since the velocity changes by an amount TU in $\frac{1}{K}$ second, the mean acceleration or change of velocity per second must $= TU \div \frac{1}{K} = TU \times K = WX$.

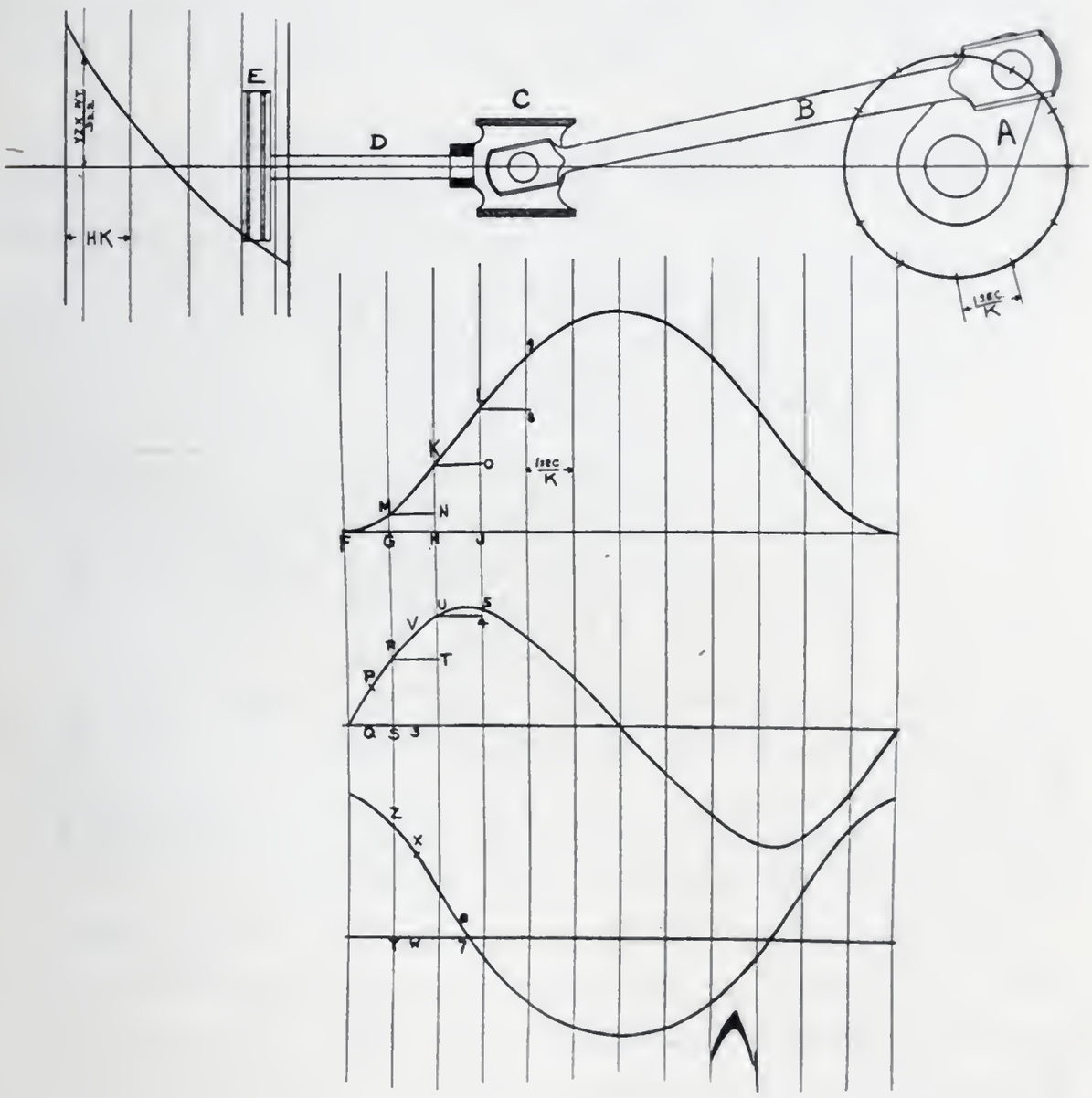


FIG. 2.

The inertia curve ZX, etc., will not be recognized by most of us who are familiar with it as laid out on indicator cards, because there the absissae are position and not time, but putting YZ on the lower curve $\frac{X \cdot WT}{32.2} = YZ \times \frac{WT}{32.2}$ on diagram drawn below piston E we have the well-known inertia curve of reciprocating engine parts.

The last problem in inertia that we will consider to-night is that of the fly-wheel.

Adding to the inertia curve for reciprocating parts just obtained, the indicator card of the engine in question, and also other courves for the effect, if any, produced by gravity on the moving parts, we can transfer the forces by the principle of lever arms to the rim of the fly-wheel, whose weight we know or assume.

Right here we might mention that considering the connecting rod, half as acting with the reciprocating parts and half with the rotating parts, we will get almost exactly the correct inertia line. Also that if the engineer has a planimeter at his disposal a very neat way of reducing the indicator card, etc., into the crank effort diagram or forces acting tangentally on the rim of the fly-wheel, is to measure the areas of the parts of diagrams, etc., between the equal time verticals. By the principle of conservation of energy, there being no point between the piston and fly-wheel rim where energy can get away (excepting friction, and that is supposed to be uniform and is neglected), the energy represented by areas on the indicator card between equal time lines must be equal to the energy represented on the crank effort diagram between the same equal time lines, which relation gives us the height of the mean ordinate and enables us to plot a point midway between the time lines. This avoids a confusing number of lines on the drawing, and has been found very accurate.

To return to our subject, we have the forces acting at the fly-wheel rim produced by the engine. We can also plot the forces reacting on it from a knowledge of our load. This in case of an electric generator is considered uniform, or in the case of an air compressor can be plotted in the same way as the engine forces.

It will be found that there are few points where these two sets of forces are equal and by our law of inertia, the mass of the fly-wheel must supply inertia equal and opposite to the difference between the other forces. Here our problem is the same as the first one considered, and though apparently complicated will be found just as simple and worked out in the same way with one difference only.

The rapid motion of the fly-wheel would make our position curve an exceedingly steep line, but as we are concerned only with how much this position changes from what it would be if it were uniform, we move the base line of our velocity curve up from O velocity to the point of uniform velocity. This enables us to keep the diagram on the paper, and gives us the same results as to change of position as if we left it where it was. It is generally necessary also to change the scale of our curves in passing from one to the other, to keep within reason. Whatever change may be necessary is embodied with K in the setting of the proportional dividers and gives us no further trouble.

Thus we see when we have dragged inertia from its hiding place and made it sign its name upon our drawings, that it really is a great aid to us in building engines. In a gas engine, for instance, especially the horizontal double tandem form that is now coming to the front, as built here and elsewhere, the inertia greatly reduces the effect of the high explosive pressures on the crank pin, and may even produce the unexpected result of giving us almost as uniform turning moment as a steam engine. (See Fig. 3.)

DISCUSSION.

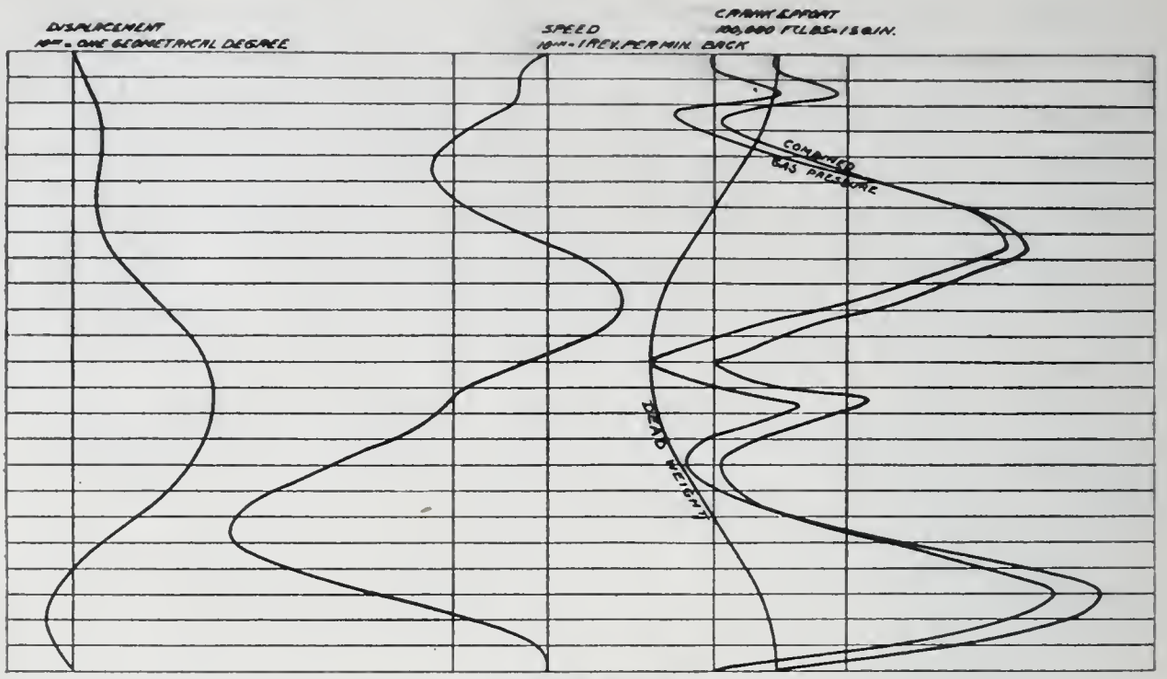
MR. SNYDER—Will you explain that Kth of a second, please?

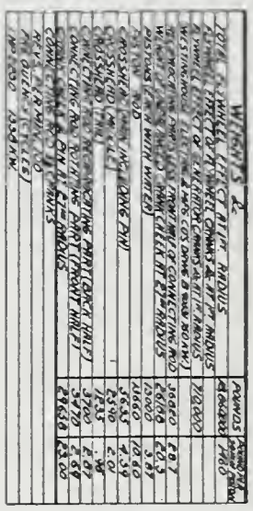
MR. KASLEY—It is customary for me in my work to divide the crank circle into 24 equal parts, so that the value of K is one twenty-fourth of the period of the revolution of the engine.

MR. SNYDER—Isn't there an analytical short-cut we can use to get the inertia at a particular point?

MR. KASLEY—There is an analytical method, a short-cut method for doing that, but the trouble with most people is they generally find they have forgotten it when they want to use it. This other method is founded on the base principal and it is hard to forget. That is the chief advantage I claim for this method. The other method is shorter.

MR SNYDER—Suppose you wanted to determine the amount of compression to carry on any given engine and want to figure quickly what is the effect of the inertia towards the end of the stroke?


DISPLACEMENT
10mm = ONE GEOMETRICAL DEGREE
SPEED
10mm = 1 REV. PER MIN. BACK
CRANK EFFORT
100,000 FT. LBS. = 1 SQ. IN.
COMPRESSED GAS PRESSURE
DEAD WEIGHT



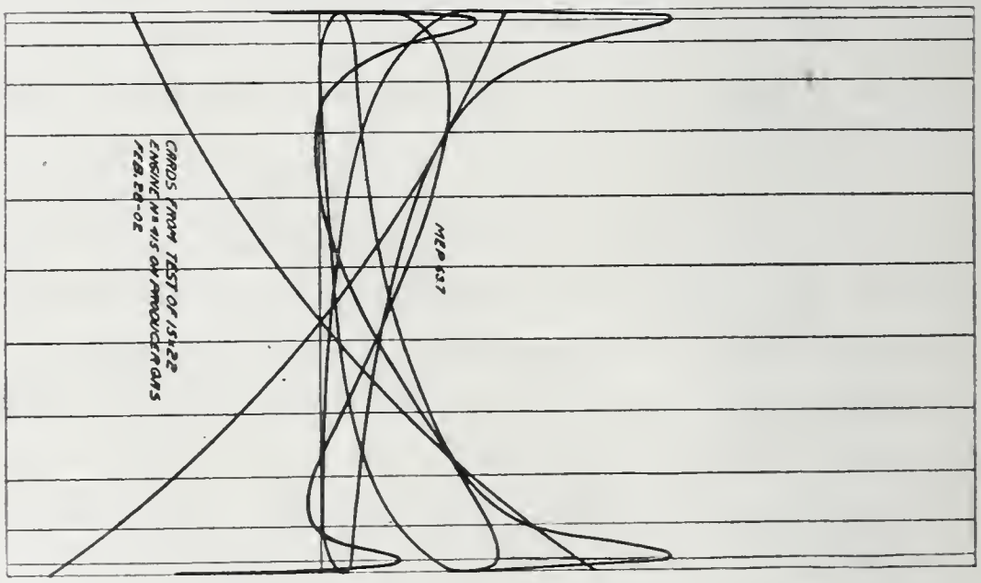

CARDS FROM TEST OF 15422
ENGINE WITH OIL PRODUCER GAS
FEB. 28-02
MID. ST.

FIG. 3.

MR. KASLEY—In other words, the extreme point. If you fill in the weights you will get practically the same point as that. You can put in the correction and get the exact crank value. If the connecting rod is five times the crank, then the value at the head end of the stroke will be the centrifugal force times 1 plus one-fifth, and the tail end of the stroke will be one minus one-fifth.

MR. ELLIS—Do you take the weight of all the moving parts and consider them as rotating on the crank point?

MR. KASLEY—In work of this kind you get the most exact results by taking all the reciprocating parts and about half the connecting rod. The connecting rod partly reciprocates and partly rotates, so that taking half of it will give you an almost exact value.

MR. ELLIS—You consider that as going right on the crank point?

MR. KASLEY—Yes, sir.

MR. SNYDER—I would like to ask about the indicator mentioned for determining the inertia. Is it a distinctive instrument similar to the regular steam engine indicator?

MR. KASLEY—It can be built on very much the same lines by substituting for the piston a heavy weight, allowing the whole instrument to reciprocate on the cross-head; and the inertia at any time will be represented by the force which the indicator spring has to impose against the tendency of the weight to move. If I had to construct one on short notice I would take an indicator and attach it to the cross-head with the cylinder parallel with the motion of the cross-head and in place of the piston of the indicator I would attach a large weight, comparatively speaking, which was free to move, being controlled only by the indicator spring. Then the string of the drum, being fastened stationary at any point, the drum would revolve as the cross-head moves back and forth, and the inertia of the parts would be represented by the inertia of this weight which would deflect the spring more or less according as the inertia was greater or less.

MR. CRONEMEYER—I would like to ask about the disturbing influence of the counterweight.

MR. KASLEY—If we remember that at one part of the stroke the engine has to lift the counterweight, thereby doing a large

amount of work which holds it back, and in another part of the stroke the counterweight is falling and it is working with the engine, thereby increasing the speed.

It is customary in considering vertical engines to get the force due to inertia by simply adding a horizontal line on the indicator cards the correct distance below the zero line, and a very easy way to do that is to drop your inertia line the required distance in one case and raise it in the other.

MR. FLINT--One question was asked a few minutes ago and I did not quite understand the answer. It referred to that 1+1/5. It seemed to me that inertia at the end of the sroke would be computed by taking the total weight of the reciprocating and revolving parts and multiplying by that 1+1/5 and 1—1/5.

MR. KASLEY--If I understood Mr. Flint's question he is right in one way and wrong in another. If you are after the effect on the crank effort diagram then you should only take half the weight of the connecting rod into account, but if you are after the pressure on the crank pins at the end of the stroke then you must take in the whole of the connecting rod because the revolving weight in that case has the same effect as the reciprocating weight.

MR. JAMES—I would like to know what happens after you get the curve. How is the inertia of the fly-wheel affected by that curve?

MR. KASLEY—The rule is, in working this out, to assume a certain fly-wheel. That would be 1,000,000 pounds, or anything. Then if the displacement comes out greater than is assumed the fly-wheel has to be increased or decreased in proportion to whether this quantity is greater or less than what is required. If the displacement comes out half as great as you want it, you don't have to go back any, you simply divide the assumed weight by two to get the weight you are after.

MR. ARNOLD—Mr. Chairman, a point occurs to me, in this connection, as one of the perplexing problems of reciprocating design; that is, the effects of inertia of alternators in parallel and of the effect this disturbing element has on the synchronizing force of generators so operated.

In looking at the diagram presented, it appears to me that if we had a reciprocating engine driving an alternator which was

not giving the required degree of regulation for the engine to operate in parallel, would it not be possible to determine the point in the stroke where the disturbance was set up, or that part of the revolution where the fly-wheel was running ahead or lagging so far behind as to set up cross currents which were in excess of the allowable amount for satisfactory parallel operating, and then to use a counter disturbing force in the form of a weight so disposed on the fly-wheel or the generator rotor as to more or less overcome the primary disturbance?

I would like to hear from someone if that has ever been worked out and what would be the probable result.

MR. KASLEY—I happen to know that that very thing was proposed in one case, but the foundations and bearings were not sufficiently strong to resist the centrifugal force due to such a weight so that its use had to be abandoned.

MR. FLINT—Mr. President, I would like to ask Mr. Kasley whether the curve for the counter-weight there shown is for the whole counter-weight or for that portion of the counter-weight which isn't directly balanced by some revolving part?

MR. KASLEY—That is for the unbalanced counter-weight.

MR. SNYDER—All this discussion has referred to engines with fly-wheels. I would like to know if this method is applicable to engines without fly-wheels simply for the purpose of counterbalancing, and if so, what modifications are necessary, if any.

MR. KASLEY—I don't think this method could be used in relation to engines without fly-wheels, if we refer to the vibration produced by them, to the vibration produced by the reciprocating parts on marine engines, for instance.

MR. SNYDER—Yes, or heavy mill engines when the reciprocating parts are moving very rapidly back and forth; for instance, if you wanted to calculate the engine to find out whether it was properly counterbalanced and what effect was being produced on the quarter-boxes.

MR. KASLEY—Well, this method is not applicable to the stresses produced on the foundation, the jar of the building or anything of that kind, but it will work well if the engine does not run evenly; that is if it runs perceptibly faster in some parts of the stroke than others.

MR. STUCKI—We have a similar case in counterbalancing locomotives—although the object is not so much to get a uniform velocity as to reduce the shocks on the frame and the tracks. In this country usually one-third of the reciprocating parts and all of the revolving parts are counterbalanced. In some parts of the West, where sand tracks exist, however, a smaller portion or none of the reciprocating parts are counterbalanced, so that the shocks due to these reciprocating parts are mostly or completely taken up by the frame instead of by the track; as it is claimed by some western railroad managers that it is easier to repair the frame than the track.

MR. FLINT—There has been an interesting experiment performed at Perdue University by Prof. W. F. M. Goss. A locomotive was supported on wheels journaled underneath its driving wheels. Different counter-weights accoring to different systems were put in, and then a copper wire was run between the two wheels, and the variation in compression of that wire indicated what the track pressure would be. There were sometimes spots where the wire was not crushed at all, showing the upward force due to the overbalance of the counter-weight would be sufficient to lift the wheels entirely off the track. At other points of course, where the counter-weight was going down, the wire was very thin.

MR. JAMES—Mr. Chairman, I would like to know something about what has been accomplished in fly-wheel work. With our multiple pole generators, where the variation is not one revolution, but a very small arc of a revolution, what is now considered reasonable practice in percent, approximately?

MR. KASLEY—The electric companies in general allow a total displacement equal to the manner of poles divided by twelve. In an ordinary generator, 100 R.P.M., we have 72 volts and only one-sixtieth of a degree displacement is allowable, and that requires a pretty heavy fly-wheel, and it has been found that by actually measuring the displacement, if it is measured before they are run in parallel, the displacement is found as in the diagram, but after they have been thrown parallel the synchronizing force generally multiplies it by two or more.

MR. ELLIS—In the course of Mr. Kasley's remarks, he said, if you will look over the diagram, you will note that there is no difference, or very little difference, between the ordinary gas engine and the ordinary steam engine. That inferred that the fly-wheel would not need to be any larger than you use on the steam engine. My understanding is that you usually put a larger one on a gas engine for that reason.

MR. KASLEY—This diagram was made for a tandem double-acting gas engine, and it is very different from the ordinary gas engine. It is true that you would need a very much heavier wheel on this kind of engine than on the steam engine.

MR. HASLEM—I didn't quite understand the remarks about the weight of the fly-wheel as compared with the steam engine. I fail to see yet where the gas engine has any great benefit.

MR. KASLEY—I think if you would compare the crank effort diagram, just as you see it there, you will find there is very little difference.

MR. HASLEM—That is what I don't understand when your initial pressure is two or three times as large.

MR. ARNOLD—Mr. Chairman, I believe that what is meant to be conveyed by Mr. Kasley's remarks is the fact that as the gas engine, taken as an illustration, is a tandem double-acting machine, it necessarily has a greater weight in the reciprocating parts than would ordinarily be put into a corresponding steam engine, but the fact that we do have a large weight of reciprocating parts in proportion to the piston diameter of the gas engine, this weight accrues to its benefit when the inertia developed is taken account of in connection with the peaked indicator card of gas combustion in the cylinder. The resulting crank effort diagram is smoothed down therefore so as to approximate very closely that of a steam engine diagram where the weight of the reciprocating parts is a great deal less than that of the gas engine, but where they have no sharp peak of pressure at the beginning of the stroke or compression at the end to react against.

(Paper read before the General Society at the March meeting.)

PRESENT ELECTRIC RAILWAY PRACTICE.

BY CLARENCE RENSHAW.

The first commercial electric railway in operation was opened for traffic in the suburbs of Baltimore, Md., in 1885. Two years later, in 1887, there were in the United States about twenty railways having together 100 electric motor cars. In 1903, less than twenty years later, the number of electrically equipped cars in this country was placed at 55,000 and the total capitalization of electric railway enterprises, to-day, is estimated as $2,500,000,000.

Remarkable as are the above figures in regard to the growth of electric railways, there is a fact in regard to the engineering side which is perhaps even more remarkable. On one of these early electric railways, viz., that built in Richmond, Va., in 1887, under the direction of F. J. Sprague, there were the following technical features:

The electric current was supplied by constant potential generators, at a pressure of approximately 500 volts.

This current was distributed to the cars in multiple by a single overhead trolley wire, supplemented by heavier feed wires in parallel with it.

The return circuit was formed by the track rails, which were bonded together and reinforced by copper conductors.

The cars received their current through an under running trolley mounted in the center of the car roof, and arranged for a universal swiveling motion in any direction.

There were two motors per car, one mounted on each axle. These motors were centered on the axles to which they were geared, and the free sides were flexibly suspended from the truck.

The motors were of the direct current series type and had the brushes fixed rigidly in a position suitable for rotation in either direction.

These features which were incorporated in one of the first twenty-five electric railway ever built, are still retained at one present time. Most of the essential elements of present practice were thus begun at a very early stage of the art and the changes of the intervening years have been largely in the nature of development, of details rather than of radical change. Only one entirely new element has been introduced, and this is the rotary converter. This machine permits the generation and transmission of power as alternating current and its conversion to direct current, at a point near where the power is to be utilized. Even this one new link is not universally used, but only in certain cases.

In pointing out briefly the present practice in regard to the equipment and operation of electric railway systems, the subject may be logically divided into three parts. These are, first, the generation of the electric power; second, its transmission and distribution to the cars; and third, its utilization at the cars.

Since the third item, that of operating the cars is really the end sought for, and the first and second items are merely means for its accomplishment, we will reverse the logical order and consider this item first.

OPERATION OF CARS.

Motors. The power required to operate a car in any of the usual kinds of service varies greatly from moment to moment. In order to obtain a proper understanding of the matter it is not sufficient to consider this power as horse power alone, but it must be resolved into its two elements, torque, (or tractive effort), and speed. To maintain a car at uniform speed on a level track requires a comparatively small torque. On a heavy grade, however, a large torque is necessary. But to start a car, even on a level, requires a very large torque, althought the speed in this case is not great. A motor intended for railway service must thus be capable of producing large torques and must also be able to operate satisfactorily under wide variations of load.

The power developed by an electric motor depends on two factors—the field magnetism and the armature current. The torque developed depends on the product of these two, but the speed, under a given set of conditions, depends on the field magnetism alone. The speed varies inversely as this magnetism, so that increasing the field magnetism, decreases the speed, while decreasing the magnetism, increases the speed.

There are two kinds of electric motors. In one of these—the constant field (or shunt) motor—the field is supplied by a separate circuit and remains constant at all times. This motor runs at a practically constant speed at all loads and consequently a large torque means a large horse power output and therefore a large power input from the supply line.

The other type—the variable field (or series) motor—has its field circuit in series with its armature, and the field magnetism therefore depends directly on the load and increases with it. An increase in current in such a motor, increases both factors which make up the torque, and moreover such an increase in current decreases the speed. A large torque therefore does not mean a correspondingly large output and input.

If motors of the constant field type were used on cars, it is evident that they would be poorly adapted to produce the large torques necessary in starting and on grades. Again, on grades where large torques were necessary, the car would run at substantially the same speed as on a level where only a small torque was required. There would thus be a heavy load on the power house in the first case and a very light one in the second, and in general, there would be considerable fluctuation in the demand for power.

Motors of the variable field or series type, are well adapted for producing large torques, since the torque increases much more rapidly than the current, i.e., doubling the current usually giving about three times the torque. With such motors, moreover, on a level where the torque needed is small, the speed of the car will be high, thus tending to increase the output, while on a grade where a large torque is needed, the speed will be low, thus keeping down the output. Thus there is a tendency for the

motor to work at a uniform output and maintain a steady load on the power house.

The series type of motor is hence well adapted for railway work, and the use of such motors exclusively is an important item of present practice.

Speed Regulation. As has already been mentioned, the speed of the series motor with constant applied voltage, depends on the torque. If a different voltage is applied, however, the speed with a given torque will be different, depending on the voltage. This fact gives a means of regulating the speed of a car equipped with such motors.

Power is supplied to the car at a nominally constant voltage, and the speed which this gives with any particular torque is, of course, the maximum that can be obtained. By reducing this line voltage before it is applied to the motors, however, any desired reduced speed can be had.

Reduced voltage of any desired value at the motors is secured from the constant line voltage, by passing the current through the proper amount of resistance on its way to the motors. This method of controlling the motors, however, involves a considerable loss of power at reduced speeds, since the difference between the voltage at the motors and that of the line, multiplied by the current flowing, represents energy which does no useful work, but is expended in heating the resistance.

If there are two motors on the car, and these are connected in series, so that the current flows first through the one and then through the other, the voltage at each motor will be only half of that of the line. If the connections are now changed so that the current flows independently through each motor, each motor will then get the full line voltage. This arrangement enables two speeds to be obtained without the use of any resistance, and a combination of this method, with the resistance method of control, reduces by half the power lost in securing the necessary speed control of the car.

A combination of switches, arranged to be operated in the proper sequence by the movement of a single handle and effecting the above connections, is called a series-parallel controller.

The use of this is the standard way of obtaining speed control in a modern electric car.

Mechanical Arrangements. In order to take advantage of this series-parallel arrangement, there are always two or four motors on a car. This also gives a greater part of the total weight on the driving wheels, and leaves a reserve, in case of accident to one of the motors.

Large motors are occasionally made to be mounted directly on the axle without the use of gears. These are called "gearless motors." Such motors are usually built with a hollow shaft through which the axle passes. Power is transmitted from the shaft to the axle by suitable springs.

Usually, however, the motors are mounted on the axles, with one side of the frame resting on the axle, and the other supported from the truck. Power is communicated from the motor shaft to the axle by a pinion on the shaft, which meshes with a gear on the axle. On account of the single pair of gears thus used, such motors are called "single reduction," to distinguish them from earlier ones, which had double reduction. Single reduction gearing is the modern method of connecting railway motors to the car axles.

How Current is Supplied. Current is supplied to the car from a bare wire suspended above the track, against which runs a copper wheel carried on the end of a pole on the car. Heavy springs at the base of the pole keep it pressed against the wire.

In some cases where the cars run over private rights of way, and where heavy cars requiring a large amount of power to operate them are used, the current is supplied by an additional rail placed beside the track rails. Iron current collectors or "shoes" rubbing on this rail gather up the current.

Size of Motors. The dimensions of railway motors are limited in general by the space available under a car, without raising the car so high from the ground that it will be unsuited for quick ingress and egress of passengers. For city cars, a wheel 33″ in diameter is considered the maximum. For interurban work, 36-inch wheels are generally used.

Cars for city service are seldom equipped with less motor capacity than two 25 H. P. motors. On the other hand such

equipments rarely exceed four 50 H. P. motors, the exact size of the equipment in any given case depending on the weight of the car, the speed at which it is run, and the frequency of stops. Cars for interurban service are equipped usually with four 50 H. P. motors, four 75 H. P. motors, or two 150 H. P. motors. In some cases, however, equipments as large as four 125 H. P. motors are used.

The largest size of railway motors now in use under passenger cars are motors of 200 H. P. each. With the present limitations of space, it seems probable that this will be the limit. Larger motors are in use on electric locomotives, where more room can be had for the motors.

The rating of a railway motor in horse power is frequently misunderstood. It does not mean the load which the motor may carry continuously, as does the rating of electric motors for ordinary kinds of work, but it refers rather to the maximum output which the motor should usually be called upon to give during the variable loads of service. The equivalent steady load which a railway motor will carry continuously is generally about one half of its horse power rating.

TRANSMISSION AND DISTRIBUTING SYSTEM.

Voltage. The pressure at which electric power is supplied has an important bearing on the economy of construction and operation of a railway. Just as a larger flume is necessary to carry the water for a given power output if the fall is low, so larger conductors are needed to carry the current for a given electric output, in inverse proportion to the voltage. Owing to the inherent characteristics of the direct current railway motor, the maximum voltage which has been found practical, is about 600 volts. The voltage of direct current generators, too, is limited, although the limit is somewhat higher than that of motors, on account of their larger size. The voltage of the entire system is limited, however, by that of the motors, to approximately 600 volts.

Feeders and Return Circuit. It has already been noted that power is supplied to the cars by a trolley wire or working conductor suspended above the track. The other side of the circuit is formed by the track rails. The trolley alone is usually not

sufficient to transmit the power for the entire system. It is supplemented by a number of heavier conductors carried along on the same poles and connected to it at frequent intervals. The side of the circuit formed by the track rails is generally sufficient, except that as the fish plates do not make very good electrical contact between rails, adjacent rails are connected together by copper wires or cables called "rail bonds," "bond wires" or simply "bonds."

In the transmission of the power from the generating station to the cars, through the conductors, a certain loss of power in the conductors always takes place. There is also a drop in the pressure. If the conductors are not of sufficient size, the power lost in transmission may become a considerable item of cost and the drop in pressure moreover may become so great as to interfere with the proper operation of the cars. For instance, if the pressure at the cars is only 50% normal, then the speed of a car on any given grade will be a little less than the same per cent. of the normal speed. It is thus essential that the conductors be of the proper size.

The proper size of conductor to transmit a given amount of power at a given pressure with a given loss (or a given drop in pressure) depends on the distance of transmission, and thus the greater the distance the power has to be transmitted, the great becomes the cost of the conductors for transmitting a given amount of power. There is thus a limit to the distance which power can be economically transmitted, and this limit depends both on the amount of power and on the voltage of transmission. The economic limit for 600 volt direct current railway lines is from five to ten miles from the power station.

Long Distance Railways. This distance was in general sufficiently great to enable the small electric lines first established in cities or towns, to be supplied from a single power house. When these systems grew too large and covered too great an area for this, other power houses were established in different localities. As the cars ran at frequent intervals, a power station could always supply a number of cars and could operate with fair economy.

In order to operate an interurban road, however, where it was desired to run only a single car at intervals of an hour or so, it was necessary to build power stations at distances of from ten to twenty miles apart, along the road. These power stations were small, since they supplied only one or two cars at a time and moreover they were running light most of the time, since the cars were run at infrequent intervals. Thus such power stations were costly per unit of output and were operated at poor economy. Consequently as long as the art was in this stage, few such roads were built.

Various schemes were devised to extend the distance over which power from a single generating point could be transmitted. One of these was to generate power for supplying distant portions of the line, at a voltage considerably higher than was safe for use at the motors, by means of an auxiliary generator, called a "booster," in series with the main generators. This extra voltage would then supply the drop of pressure in the line, leaving the proper pressure for the cars. This arrangement overcame the difficulty as far as pressure was concerned, but did not overcome the loss of power.

Another arrangement was to locate a storage battery on the distant section of the line and supply power to it at a voltage sufficiently high to allow for the drop in the feeder. A small amount of power could be supplied to the battery through a feeder of reasonable size, and supplied steadily all day long. The battery would then store up this power which was supplied in small quantity for long times and give it out in large quantities for short times, to supply the infrequent demands of the cars.

All such arrangements were makeshifts, however, rather than true solutions of the problem.

Rotary Converters. The rotary converter is a machine for changing alternating current into direct current. It was introduced about 1895 and has played an important part in the development of electric railways. In appearance it resembles an ordinary direct current generator except that instead of being driven by an engine or water wheel, it is run as an electric motor by the alternating current. The rotary converter thus in effect,

embodies in itself an alternating current motor driving a direct current generator.

The voltage of an alternating current circuit can readily be raised or lowered by means of transformers, without the use of moving machinery. By using alternating current for the transmission of power, therefore, the power can be generated at any convenient voltage, raised to a high voltage for transmission and then reduced again for utilization.

By the use of rotary converters, power for electric railways can be generated and transmitted as alternating current, thus using a high voltage for transmission, and being able to transmit economically, and then, at convenient points, can be readily changed into direct current for the operation of the cars. A place where such a transformation is made is called a sub-station and is in effect the same as a direct current generating station. Sub-stations, however, especially for small or moderate outputs, can be installed and operated for a much less cost than could direct current generating stations.

The development of the rotary converter therefore opened up at once an immense field for the building of long distance suburban and interurban electric railways. It was so successful in this field that it has since come into general use even for the operation of cars in cities, where in many cases a large alternating current power station, located where land is cheap and transportation for coal convenient, with rotary converter sub-stations in different parts of the city, is taking the place of a number of small direct current power stations.

The transmission and distributing system of a modern electric railway consists then of a high tension three phase line carrying the power from an alternating current generating station to a number of sub-stations, transformers for lowering the voltage and rotary converters for changing to direct current, and trolley wires, re-enforced by heavy copper feed wires for carrying the 600 volt direct current to the cars. In cities the high tension lines are usually run in conduits underground, and the voltage is from five thousand to ten thousand. For interurban roads, they are generally run on 35 foot or 40 foot poles and the volt-

age is from 15,000 to 30,000, according to the amount of power and the distance transmitted.

GENERATING STATION.

As has already been implied, the generators of the modern electric railway power-station are alternating current machines in many cases. Where direct current machines are still retained, these are of much larger size than formerly. Where railway generators of 200 K. W. capacity were once thought to be very large, generators of almost 3,000 K. W. are now in use. Instead of being belted, such generators even in comparatively small sizes are now mounted directly on the shaft of the engines so that each engine with its generator forms a compact unit. Alternating current generators for railway service have been made of even larger size than this, eleven machines of 5,000 K. W., each having been installed by a single railway company in New York (Manhattan).

Alternating current generators, too have undergone changes, and instead of revolving armature machines, those of the revolving field type are being manufactured almost exclusively.

The introduction of the steam turbine as a prime mover has also caused further changes. This has as yet been little used with direct current generators for railway service, but has found great favor in connection with alternating current machines. Generators for a given output, intended to be driven by steam turbines are much smaller and run at much higher speeds than those designed to be driven by slow speed engines of the ordinary types.

On account of the increased outputs of the generators, the various switches and other devices used for controlling and measuring these outputs have been enlarged and improved. In many cases mechanically operated switches are now used instead of the ordinary hand operated types. The switchboards on which the various instruments are mounted are made of marble or slate instead of wood, and every effort is made to keep the amount of inflammable material in the power station down to a minimum.

SUMMARY.

In conclusion, then, modern electric railway practice is toward the use of larger and heavier cars than formerly. These are propelled by electric motors of the series type, hung from the axles of the cars and connected to them by single reduction gearing. Either two or four motors are used per car and speed regulation is obtained by series-parallel controllers.

The cars obtain power in the form of direct current at 600 volts, from a trolley suspended over the track, which trolley is re-enforced by heavy feed wires parallel to it. Trolley and feeders connect usually to rotary converter sub-stations from five to fifteen miles apart.

The sub-stations derive their power from an alternating current generating station by means of one or more three phase high tension lines. And finally the power is generated in a practically fire-proof station, by large generators coupled direct to engine or turbine.



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Advance copy of paper to be read at the September meeting of the General Society.

THE PHIPPS POWER BUILDING.

BY GERALD E. FLANAGAN.

The primary object which led to the construction of the Phipps Power Building was the furnishing of power in various forms, from a central station, to a group of buildings closely adjacent to it upon the property of the owner, some of these buildings being already in existence, others in the nature of projects to be carried out in the future. A plot of ground one hundred feet square fronting on Cecil alley, between Penn avenue and Duquesne way, was set aside for the purposes of a power building, and the designers of the structure prepared the plans accordingly. This plot lies in a fairly central position with regard to the properties it is immediately designed to serve, being bounded upon three sides by ground upon which it is the intention to erect structures that will utilize the power which the present installation is capable of supplying; and, since this machinery has been constructed upon a liberal scale, looking well towards the possibilities of future demands, the troublesome question of power service has been removed once for all from any improvements to be carried out by the same interests in this vicinity. The advantages of such a central plant will be at once appreciated without need of referring to them in detail; conspicuous among them, however, being the fact that the basements of all other buildings are left free to be used for other purposes; and the concentration of power under one managment results in the installation of a more efficient type of machinery, and a marked reduction in the number of high-priced attendants. The new office structure, known as the Bessemer Building, now being supplied with light, heat and power from

this center, is the forerunner of others which are soon to follow, and, in this paper, any mention of service to the Bessemer Building implies like service to any others upon the Phipps property.

BUILDING.

The building in which the power generating machinery is housed is, as above noted, one hundred feet square and is ten stories in height, of heavy steel frame and brick curtain walls with Indiana limestone trimmings. It rests upon a massive concrete foundation, which, in turn, is carried down to a solid footing upon a bed of gravel. It is built to the property line on Cecil alley, but is located a distance of four feet from the adjoining property on the side towards Penn avenue, while the other two sides face the property of the owner, and it is the intention to maintain a space of twelve feet between them and any buildings to be erected in the future; thus giving light and air on all four sides. There are large windows on all sides which are protected by rolling steel shutters. The machinery and boiler floors are formed of concrete, between the steel beams and over them, while throughout the rest of the building the steel is covered with hollow fireproofing tile, around the columns and arched between the floor beams. These floors are then surfaced with concrete over the fireproofing. In a similar manner, the roof beams are covered with fireproofing tile and concrete, then with heavy tar paper, and surfaced with Welsh tile. This does not mean a steep-pitched roof with overlapping tile. The tile are of a hard burned clay, such as is used for vitrified sewer pipe, and they are laid upon the tar paper with flush joints filled with waterproof material, and the slope of the roof is not greater than what is required to shed water, or about one-quarter of an inch per foot.

The first three stories are twenty-four feet from floor to floor, and are occupied entirely by boilers and machinery; the remainder are thirteen feet in height, and are suitable for light manufacturing; an ample supply of power in various forms being immediately available. There are two roomy passenger elevators, each of a capacity of three thousand pounds live load, and one large freight elevator of ten thousand pounds live load capacity. The stairway is entirely of iron and steel; the treads and landings

being of cast iron plates of diamond pattern. The first, or engine room, floor is nearly six feet above the sidewalk, being so located as to be safely above the highest recorded flood stage, making it about 33 feet 6-in. above pool stage of the Allegheny river, and the building is so constructed that even with the highest water there are no openings through which it can flow into the basement. As an additional safeguard, the generator foundations are so constructed that even if the basement was filled with water none of it could find access to these machines. The basement floor is twenty feet six inches below the engine room floor, and is formed of four feet of concrete over the entire surface placed directly upon the gravel. From this base rise the outer walls carrying the exterior columns, and in the center a mass of concrete forming foundations for the large engines and heavy interior columns supporting the coal bin and the boiler and manufacturing floors. This foundation is continuous from the front to the back wall, and divides the basement into two parts, except that it is pierced both lengthwise and transversely with large tunnels permitting free communication, and serving as conduits through which the necessary piping may be carried. The flooring over these side basements is constructed entirely free from the framework of the building, and consists of twenty-four-inch one hundred-pound I beams, spaced about three feet three inches centers, filled in with concrete and covered with twenty-four inches of the same, making a floor four feet in thickness. On the side under the elevator pumps this depth is increased to five feet, by the addition of another foot of concrete. This was done to avoid any possible vibration due to the operation of these pumps. The second and third floors extend only along the sides of the building of sufficient width to carry the boilers, except that they connect by galleries at each end. The center space is thus left open to the bottom of the coal bin, which occupies the center of the fourth and fifth floors.

ARRANGEMENT OF MACHINERY.

The arrangement of the machinery will be understood by reference to the illustrations. On the first floor, in the center, are the two large engines direct connected to alternating generators,

with provision for installing a third unit at a future time. To the left of these are two elevator pressure pumps, also with a place for a third when required. On the right are located two small engines direct connected to direct current generators which serve to excite the large alternators. In this room is also located the switchboard, with ample space both in front and behind, giving free access to every part; the rear side is in strong daylight for its entire length.

At the rear of this room appears the steam end of the vertical pumps which draw the general water supply from the river, the base of these pumps being at a level of six feet six inches below the basement floor; and beneath this level again is a small sump into which all leakage in the basement collects and is pumped into the river. The remainder of the basement is taken up by the boiler feed pumps, of which there are two in place with room for a third; feed water heater with space for a second one, softening apparatus for feed water, exhaust muffler and grease separator, return water tank and small receivers and pumps for various drains. In the basement on the other side of the building are located the accumulators, a large air tank for cushion on the return line to the elevator pumps, and a pump at the artesian well which supplies the drinking water. In a small intermediate basement in front of the engine foundations are located the filters for the boiler feed purifying system.

On the second floor of the building are located the boilers, and the third floor is arranged so as to be finally used for the same purpose; thus doubling the present capacity. Above the level of the third floor boilers is the coal bin.

DESCRIPTION OF MACHINERY.

The engines are of the verticle type Westinghouse-Corliss cross compound with reheating receiver; the cylinders are 28 inches and 46 inches by 48 inches. Both the guides and the main bearings are water cooled. The fly-wheels are 19 feet in diameter, and weigh about 200,000 pounds each. They are gray iron wheels, made in four segments of 40,000 pounds each, the hub also weighing 40,000 pounds.

These engines are direct connected to 1000 K. W. A. C. 3 phase, rotary field, Westinghouse generators; they are 80-pole machines, running at 90 revolutions, giving 7200 alternations.

Over the engines and generators is a 25-ton electric traveling crane, built by Pawling & Harnishfeger, and there is a sunken way in the engine room floor which permits the entry of wagons at the street level to a point commanded by the crane, thus facilitating the delivery or removal of machinery, etc. When not in use this space is covered by a movable floor.

There are two Laidlaw Dunn Gordon special elevator pumping engines of the three-cylinder compound horizontal pattern, 21½-inch high pressure cylinders, and two 28-in. low pressure cylinders, with reheating receivers; the plungers being 6¼-in. diameter, and the stroke 24-in. These machines deliver water against a pressure of 850 pounds, the capacity being 700 gallons per minute.

Water is supplied by two vertical tandem-compound duplex Wilson-Snyder pumps with cylinders 18-in. and 30-in., 17¼-in. plungers by 30-in. stroke, which draw water from the Allegheny river and deliver it against a pressure of 150 pounds, to be used for all purposes except drinking, including fire service.

Two 12-in. by 12-in. Harrisburg engines are direct connected to 60 K. W. Westinghouse direct current generators. These are used for exciting the fields of the large alternators, and for other purposes for which direct current may be required. If at any time the demand for direct current should exceed the capacity of these machines other units can be installed, or rotary transformers may be used.

The boiler feed is furnished by two Wilson-Snyder compound duplex pumps with cylinders 8-in. and 14-in. on the steam end, and 7-in. water cylinders by 18-in. stroke.

The elevators, both freight and passenger, were built by the Otis Elevator Company, and are of their most approved pattern of high pressure machines, operating with 850 pounds hydraulic pressure. They are supplied with all up-to-date devices for operating and for safety.

The accumulators were also supplied by the Otis Company. They have plungers 12-in. diameter by 12 feet stroke, and are

weighted with cast iron rings, one being weighted slightly in excess of its mate, which is connected to a chronometer valve on the pressure pump by means of wire rope, in such a manner that the motion of the accumulator plunger starts and stops the pump. The second accumulator being more lightly loaded, will be the first to rise and the last to fall. They are arranged, however, so that if from any cause one of them be put out of commission, the other may be quickly connected to either of the pumps. These machines have automatic stop valves which throttle the water, and so bring the moving mass of iron quietly to rest at each end of its travel.

The switchboard is 7 feet 6 inches high and 30 feet 4 inches long. It has one panel for direct current, three for the alternating generators, and six distributing panels. It is of blue Vermont marble mounted upon an iron frame, and is equipped with improved forms of all instruments necessary for the control of large currents. The lead-covered cables from the generators to the switchboard are taken in conduits under the floor. These conduits are so covered that they are not visible, and cause no interruption to the continuity of the floor; but they can be opened without serious difficulty should occasion arise. The cables go from the board down through the floor to the basement, and thence through the tunnel to the Bessemer Building.

The Scaife system of treating tanks and filters is used for purifying the water before it enters the boilers. This apparatus consists of two solution tanks provided with small pumps for forcing the solutions into the precipitating tanks, of which there are also two. These latter are closed tanks, being required to withstand an internal pressure of two hundred pounds. Through these tanks the water travels very slowly, the bulk of the impurities settling to the bottom during its passage. From here the water goes to the filters, of which there are four, also of the closed tank pattern; the pressure, of course, being the same as in other parts of the feed water system.

In addition to the more important apparatus above mentioned, there are a number of small pumps used in the daily operation of the plant. There is a pump for discharging the water from the basement sump; another for taking the water from an open tank

in which the returns from various lines are collected; a receiver and pump which takes all drips from steam separators and high-pressure lines; and a small receiver and pump which takes the greasy drips from the feed water heater and the grease separator.

The feed water heater is of the closed rectangular pattern made by the Pittsburgh Heater Company. There is also an air compressor for supplying air to the cushions on the hydraulic system; and oil filters and pumps for the lubricating system.

Coal is delivered at the two large receiving doors on Cecil alley, and falls through heavy cast iron gratings into hoppers beneath. From there it is raised by two elevators, designed by Heyl & Patterson, to belt conveyors which traverse the entire length of the coal bin. Moving trippers travel the full length of the conveyors and distribute the coal evenly along on both sides.

The coal bin is of heavy steel plate stiffened with I beams; it is lined with cement plaster upon wire netting, the bottom being built into hopper forms from each pipe opening by hollow tile such as is used for fireproofing. Twelve pipes, each 12 inches in diameter, lead directly to the stokers at the boilers, and other openings are in the plates ready for the second floor of boilers.

The present installation consists of twelve boilers of the Babcock and Wilcox water tube type, aggregating 3,600 horse power rated capacity. Each boiler consists of 140 4-in. by 18 foot water tubes, and two 36-in. by 18 foot drums. They are built two in each battery, and furnished with Babcock and Wilcox chain grate stoker, this construction giving free access to one side of each stoker. The furnace gases discharge directly in the rear of the boilers; those from each boiler into a separate vertical flue provided with a damper which swings open of its own weight, and is held in the desired position to check the flow of gases by a chain. The vertical flues are 15-in. by 10 feet, and rise directly to a 4-foot by 10-foot horizontal flue. They have expansion joints about the center of their length.

The horizontal flues each have two expansion joints, and are suspended from the girders above in such a manner as to admit of the requisite motion in the direction of their length. They are provided with numerous cleaning doors.

There are separate stacks for the boilers on each side of the building. The stack proper rests upon heavy girders, but between it and the horizontal flue is a short section or sub-base which connects to the stack through an expansion joint. This sub-base rests directly over an opening in the upper side of the horizontal flue, and is also joined to it by a large connecting flue at an angle of about 45 degrees to provide a free sweep for the gases as they change from a horizontal to a vertical direction.

The stack is 11 feet inside diameter, and rises to a height of 200 feet above the grate bars. It is built of $\frac{3}{8}$-in. steel plates, except the bottom ring and the rings where it is stayed to the building at the roof, which are $\frac{1}{2}$-in. There are four substantial brackets at the base which rest upon the steel work of the building, and the top is stiffened by a ring made of two 6-in. by 6-in. by $\frac{7}{8}$-in. angles, and below this a ring made of Z bar for carrying slings for painting. A ladder extends from the roof to the top of the stack. The stacks are not lined. Around the 11-foot stacks are tile wall inclosures 13 feet square, permitting the intervening spaces to serve as ventilating shafts for the engine and boiler floors.

THE PIPING SYSTEM.

The piping system is never the least important part of a power plant, and in this instance it really constitutes itself a leading feature.

Water Supply and Boiler Feed.—On the bank of the Allegheny river is a massive concrete block which forms the intake for the water supply, and from this point two 16-in. cast iron bell and spigot pipes lead to the supply pumps in the Power Building. This intake has been built to conform to the harbor line of the river, and for this reason it is scarcely visible to casual observers. The inner end appears, when the water is at pool stage, but it is flush with the surface of the wharf and covered with a heavy cast iron plating. The screen, the tops of which are below the water even at pool stage, are formed of angle bar frames with bronze wire netting, and are dropped into slots formed in the concrete. In front of the screens is a grating made of round wrought iron

bars 2½-in. in diameter; these are dropped into sockets in massive cast iron beams and may be removed singly.

Discharging into the river at a point below the intake is private sewer from the Power Building, made of 10-in. bell and spigot pipe.

At the supply pumps the system of valves is such that each of the pumps may draw from either, or both, of the intake pipes, and also that the pumps may discharge into either of the intake pipes while drawing water through the other one, for the purpose of blowing out any sediment which may collect in them. From the discharge side of the pumps a 16-in. main leads to the various properties, a 6-in. branch being taken off to supply the general needs of the Power Building, while a 10-in. line leads to the boiler feed pumps. From the feed pumps an 8-in. line goes to the feed water heater, and from there a 6-in. line takes the hot water to the purifying system, and then reaches the boilers through various smaller branches. Valves are arranged so as to by-pass the heater, treating tanks and any one or all of the filters, so that the plant is operative with these devices entirely out of commission. The feed water mains are of wrought iron, and the smaller branches at the boilers are of brass. Near the feed water heater is a nickle-seated water relief valve set at 220 pounds.

Steam Pipes.—Steam from the boilers is collected in 14-in. headers on either side of the building, and these are connected at one end. From both headers 10-in. lines lead to the separators at each of the large engines, so that each engine may draw steam from any or all of the boilers.

Exhaust Steam Pipes. Exhaust steam leaves these engines through 18-in. pipes which are collected into a 24-in. line and finally into a 30-in. main and stack, which terminates in a large exhaust head above the roof of the building. Since exhaust steam is to be used for heating during a greater part of the year there is a 30-in. back pressure valve located in the horizontal main; and behind this valve are collected branch lines from all the steam-using machinery, but arranged in such a way that while the smaller machinery is working under back pressure the main engines may exhaust freely to the atmosphere, and by operating

the proper valves the exhaust from these engines may also be forced into the steam heating mains.

Waste Steam.—The steam wasted through the safety valves is collected into two 8-in. mains which in turn discharge into the 30-in. stack. The branches enter these mains at an angle of 45 degrees to permit an easy flow of steam.

Boiler Blow-Offs.—From the boilers on each side of the building the blow-offs collect into short 4-in. mains, and these in turn join and form two 5-in. lines which discharge into the private sewer. A branch from the filter blow-offs also leads into one of these 5-in. lines.

Hydraulic Lines.—The elevator pressure pumps discharge into 8-in. pipes, and these lead into a 10-in. main from which branches are taken to the pressure side of the machines. A 6-in. branch is also taken to the accumulators, and on this branch is located a large air chamber fitted with a valve to prevent the air from escaping should the pressure in the line fall from any cause. The return water from the elevator cylinders comes back to the Power Building through a 14-in. bell and spigot pipe and goes directly to the suction side of the pumps, the portion of the line within the building being of galvanized steel pipe. There is a large air tank on this line to cushion the shock of the moving body of water. A 6-in. branch from this line goes directly to a wooden tank above the roof of the Power Building. This tank acts as a reservoir, and its altitude is sufficient to maintain a pressure of about 75 pounds against which the machines must discharge. The object of this arrangement is to guard against the possibility of the cylinders emptying themselves, as they are placed vertically and contain a column of water of much greater height than the atmosphere would support. The large operating valves of the elevators are moved by cylinders operated by small pilot valves, and these small valves take water from the 75-pound line and discharge it at atmospheric pressure. This water returns to the open tank and is saved, as it is of value, having been previously treated and filtered.

Return Water Lines.—A small amount of live steam is used in the office buildings for heating water, and the condensation

from this is returned to the open tank, as is also that of the exhaust steam from the heating system and the discharge from the elevator pilot valves. The water from this tank is pumped through a 4-in. pipe to the tank above the roof, replacing the loss in the hydraulic system. When the roof tank is full, a float operated stop valve closes, and the pressure rises sufficiently to force a check valve in a branch line leading to the feed water system, entering it behind the heating and purifying apparatus.

The clean drips from steam separators, etc., are pumped directly into the feed pump discharge, and the oily drips from the grease separator and condensation in the feed water heater are pumped into the elevator pump suction line.

Piping Details.—With the exception of the high pressure hydraulic lines all valves and pipe fittings of a given size in this building are interchangeable, from the smallest size up to fourteen inches, this being the largest size used for any purpose other than exhaust steam and a few fittings directly connected to the main supply pumps. At these pumps there are some 16-in. valves and a number of special 16-in. fittings. For exhaust steam there are valves and fittings 18-in., 20-in., 24-in. and 30-in. The result is that any valve or fitting can be used in any part of the plant provided it is the proper size. Aside from the hydraulic lines, all valves and fittings are plain faced, the flanges above 6-in. being rolled steel, the fittings cast iron. All flanges and fittings have machined surfaces for bolt-heads and nuts, and the under sides of bolt-heads and nuts are faced. The bolts are made from refined wrought iron. All bolt holes are drilled, the number of holes being four in the small sizes and some multiple of four for the larger ones. The cast iron flanges are threaded in the usual way, and the rolled steel ones have grooves into which the pipe is pened. The pipe hangers are entirely of forged steel, and are of a very substantial character; they are provided with turn buckles for adjusting the length.

The flanges and fittings on the hydraulic lines are of a type especially designed for this plant. The flanges are screwed to the pipe, and are then turned in the lathe in such a manner as to leave the pipe and a portion of the flange immediately surround-

ing it projecting a considerable distance from the face. This projecting portion is slightly curved on its face, the highest part occurring on the pipe itself, and between these pipe ends the heavy copper gasket is compressed. It will be seen that there are no male and female joints in this system; all flanges of a given size are alike, a corresponding projection being formed upon the fitting. All the fittings are steel castings, the flanges being of forged steel. The elbows are of long sweep pattern and the tees are strengthened with heavy ribs. In order that the gasket may center itself readily, its outside diameter is made equal to the inside diameter of the bolt circle. A few of the bolts are put in place and the gasket slipped in between the flanges, the remainder of the bolts are then inserted and the joint tightened.

The Power Building requires to be supplied with coal, and this done, it is able to return power in various forms, such as electric current, alternating and direct; steam at one hundred and fifty pounds, or any lower pressure; water at one hundred and fifty pounds, or at eight hundred and fifty, and compressed air. At present these lines are taken through an underground conduit to the Bessemer Building. In the future, the ground through which this conduit runs will be covered with tall buildings, and the pipes will then appear in the basement of one or more of them, being already provided with branches from which lines may be taken to supply the buildings through which they pass.

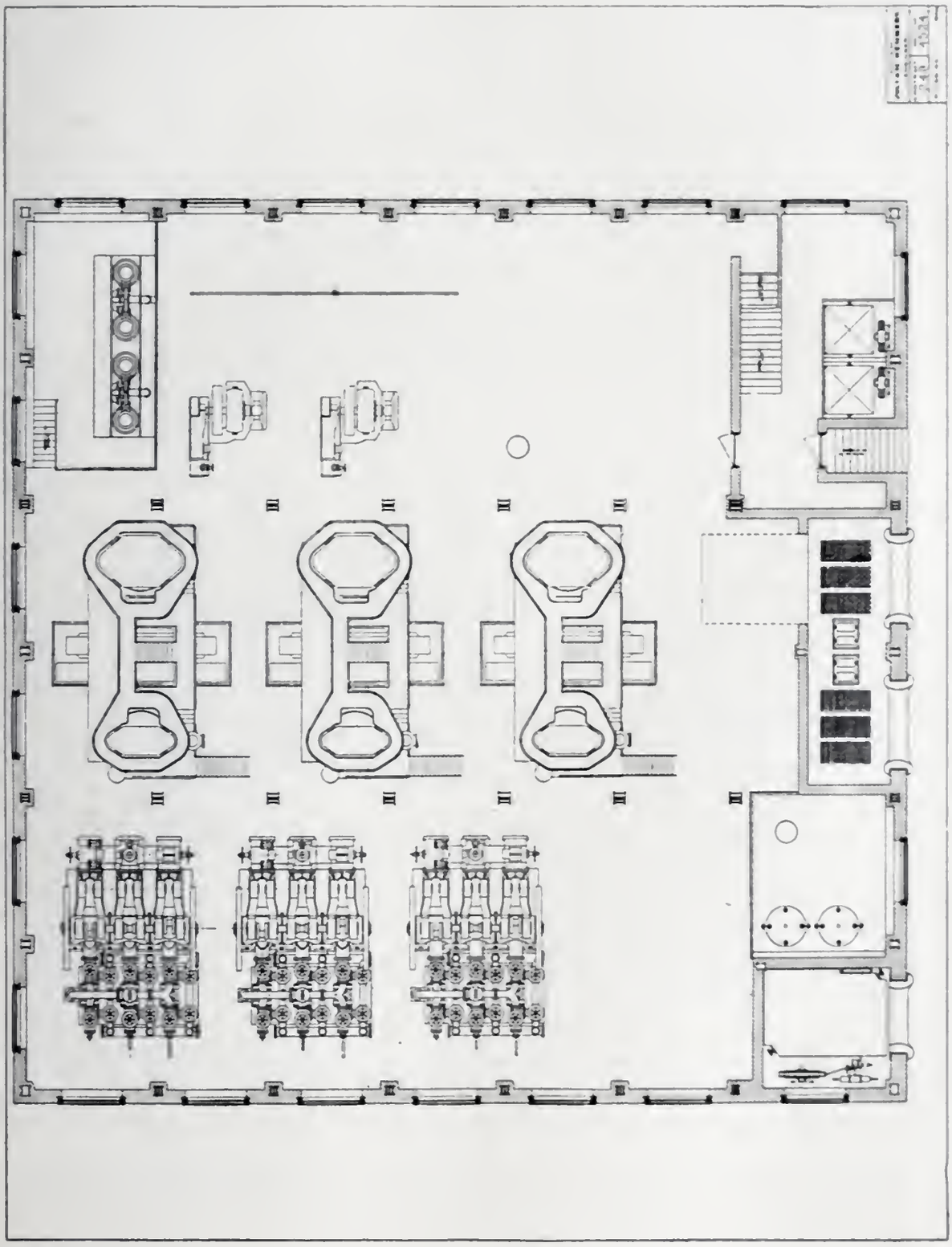


Fig. 1. Plan of Engine Room.

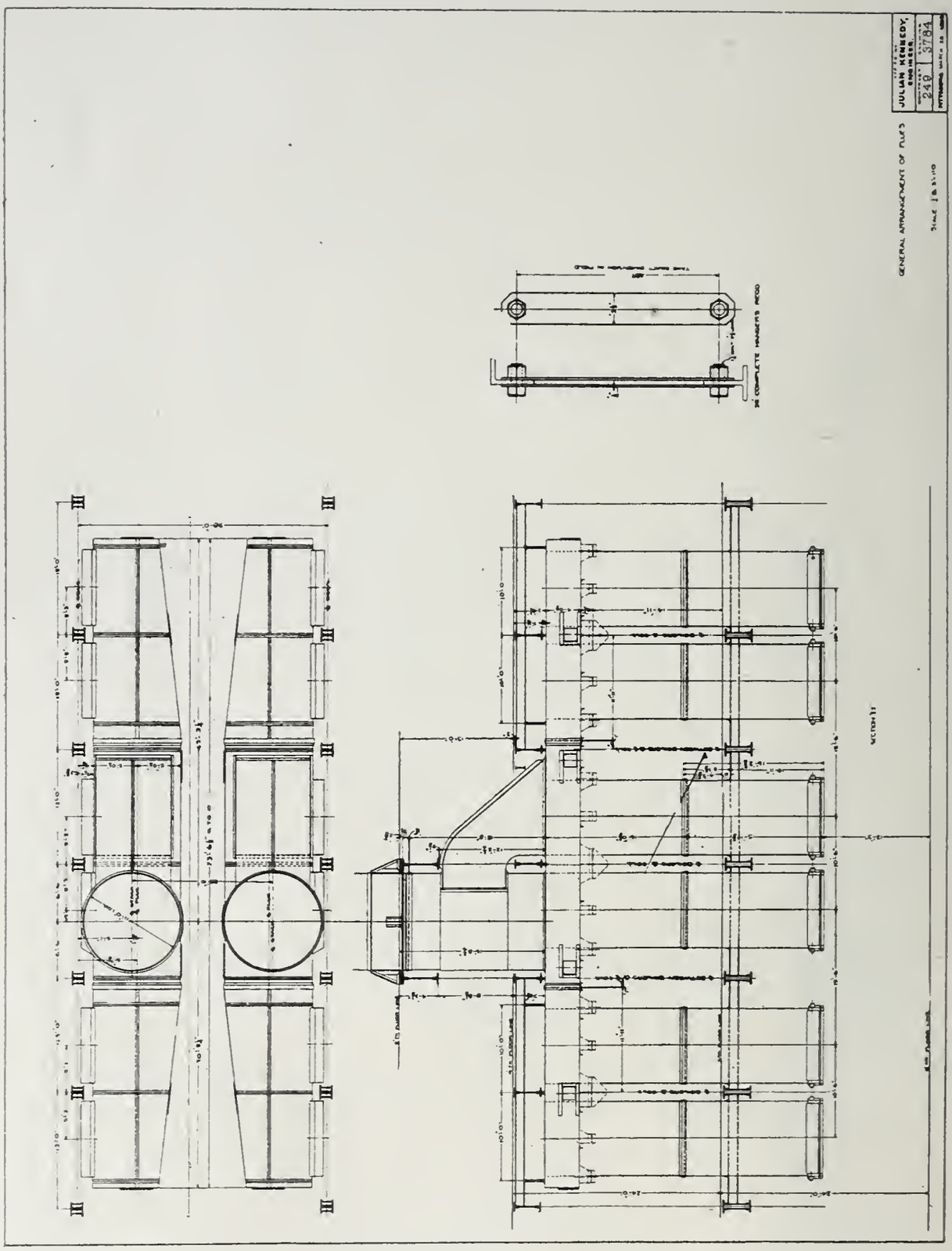
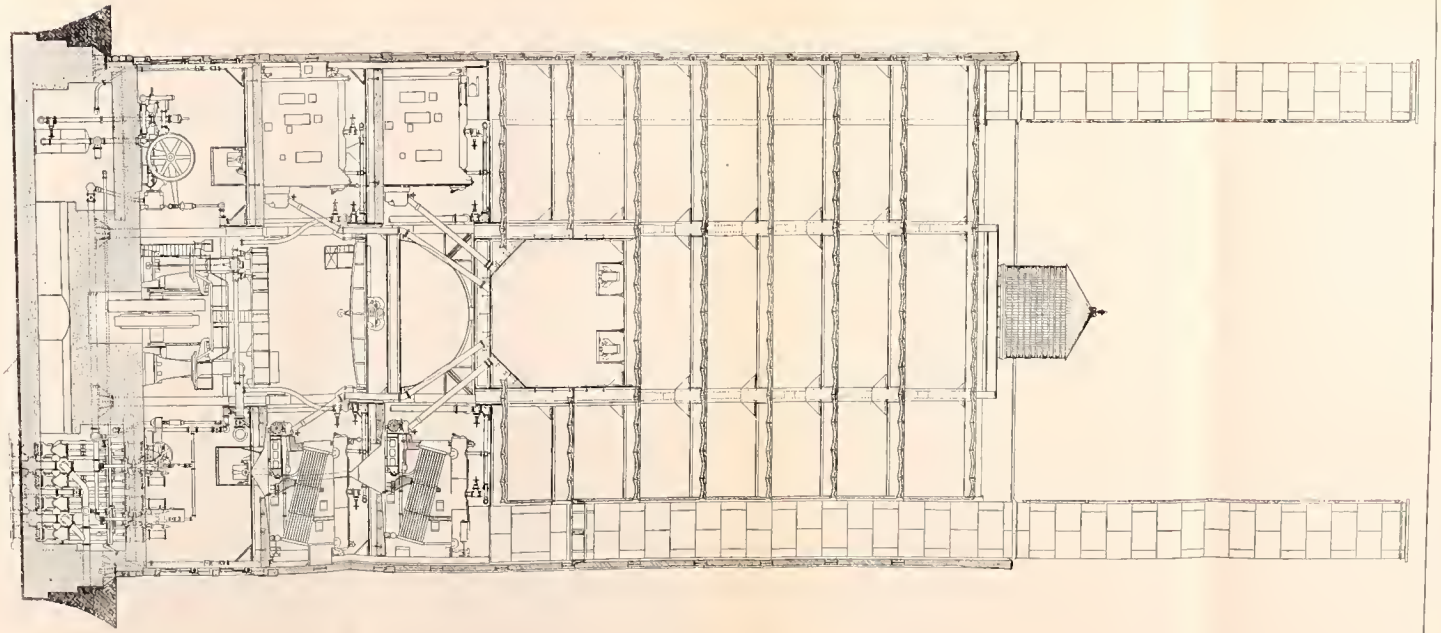


Fig. 3. General Arrangement of Flues.





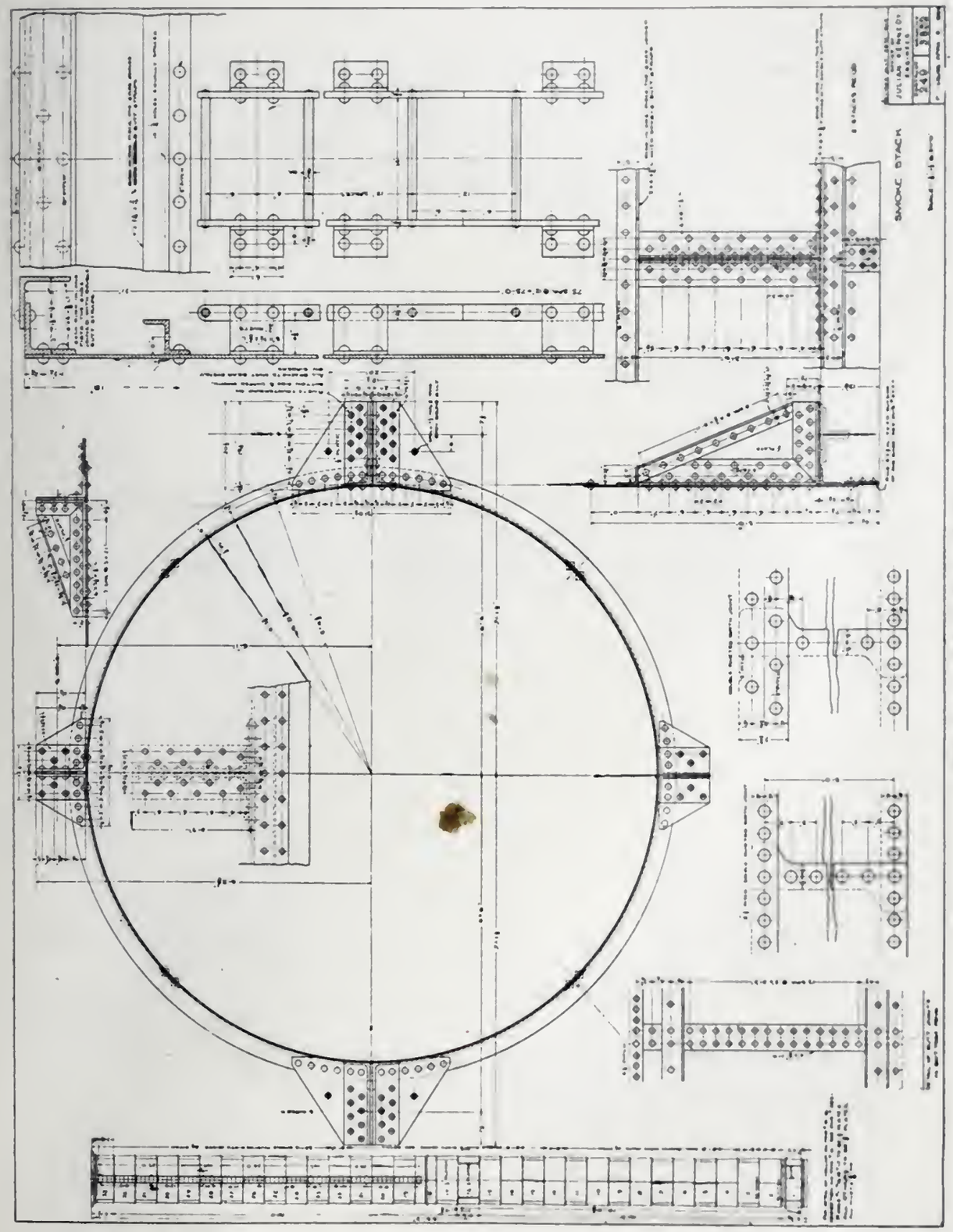


Fig. 4. Details of Stack.

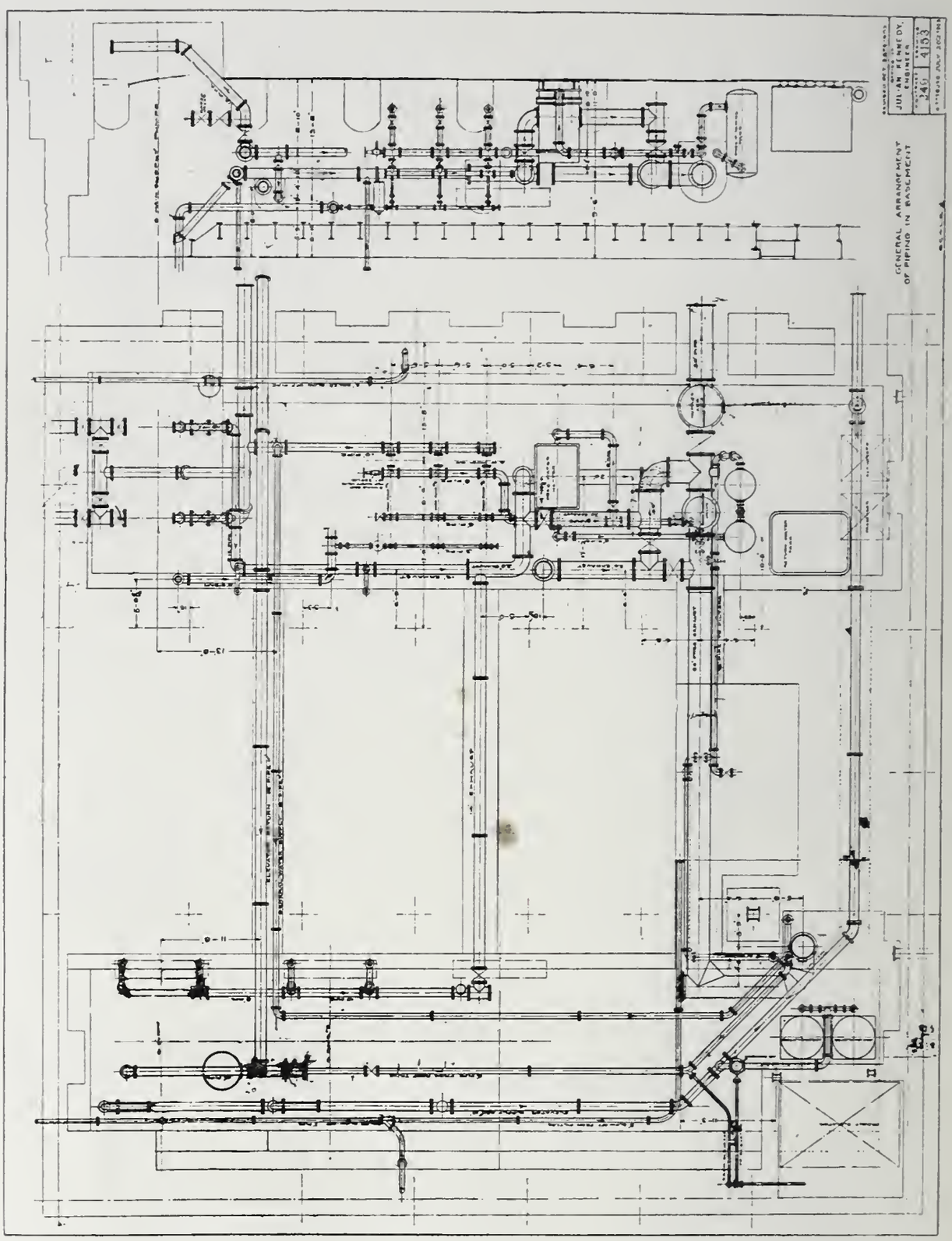


Fig. 5. Plan of Piping in Basement.

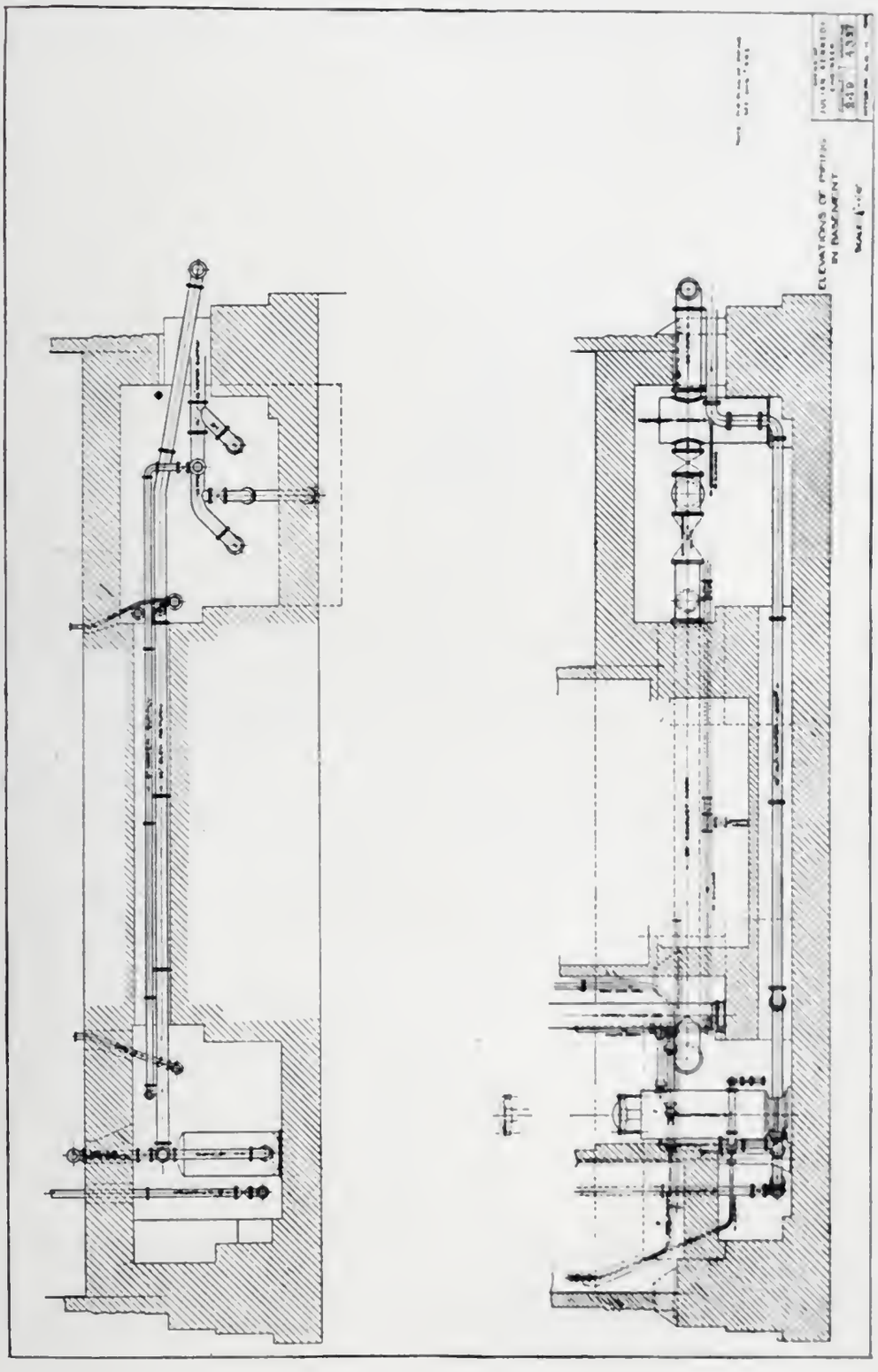


Fig. 6. Elevations of Piping in Basement.

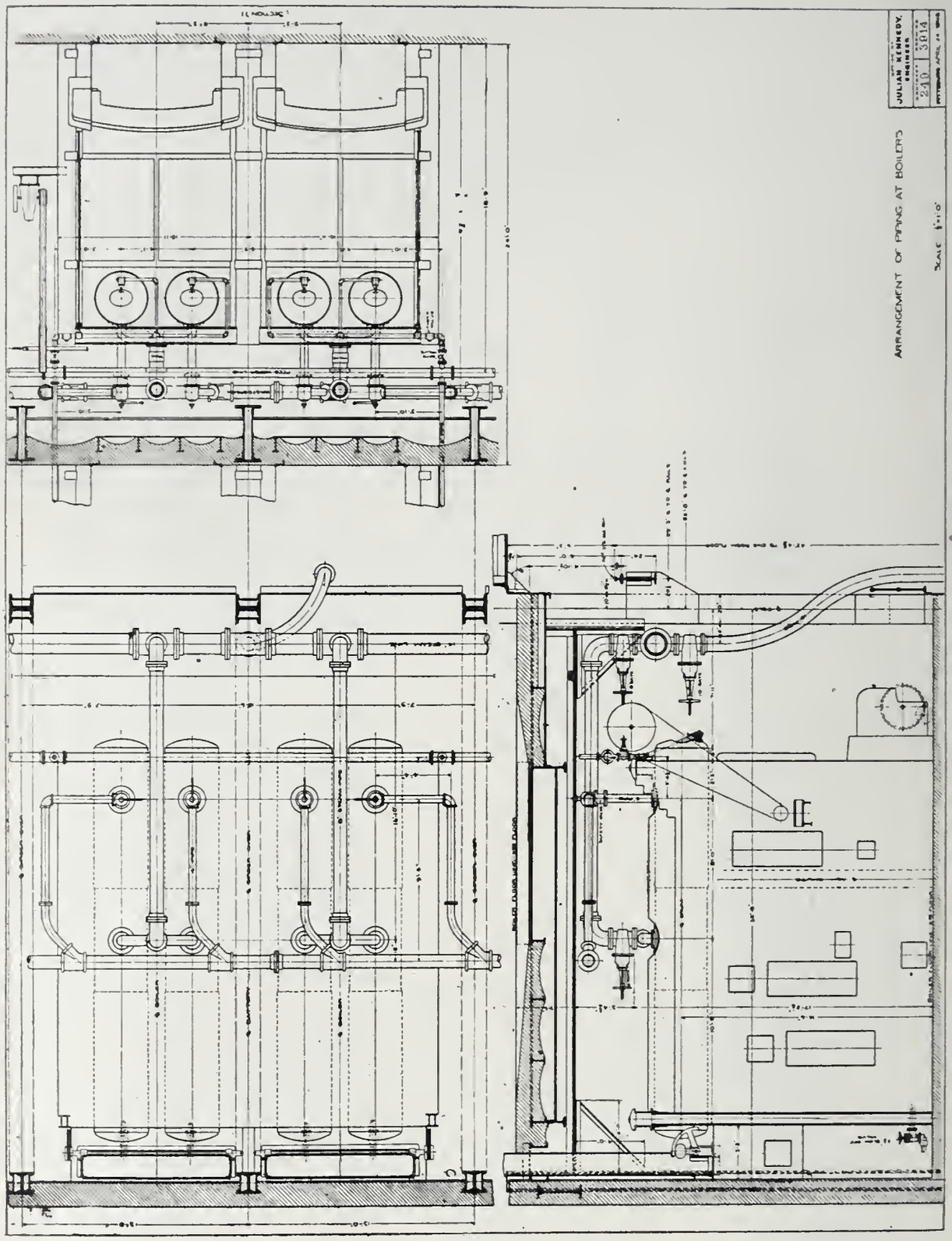


Fig. 7. Arrangement of Piping at Boilers.

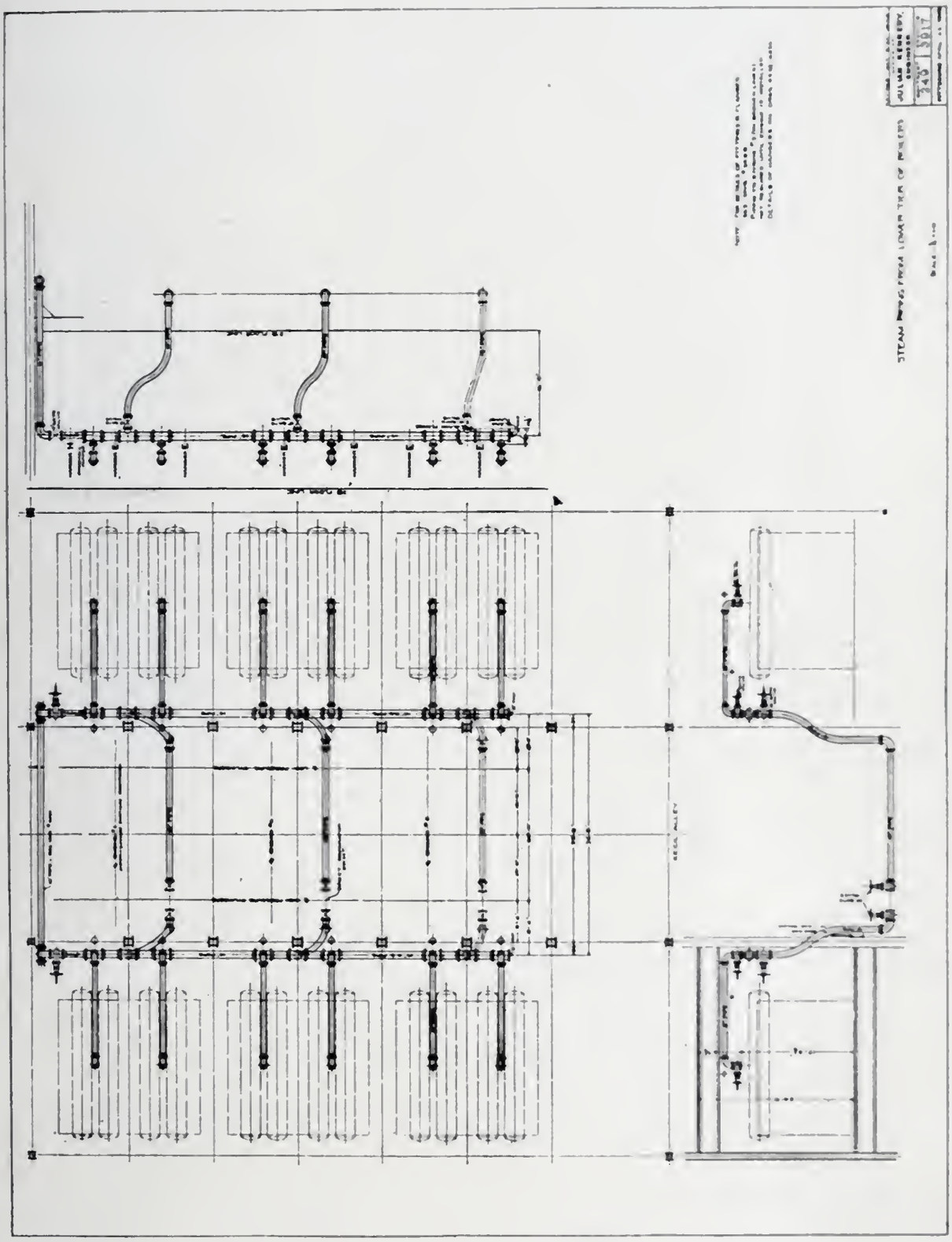


Fig. 8. Steam Piping from Lower Tier of Boilers.

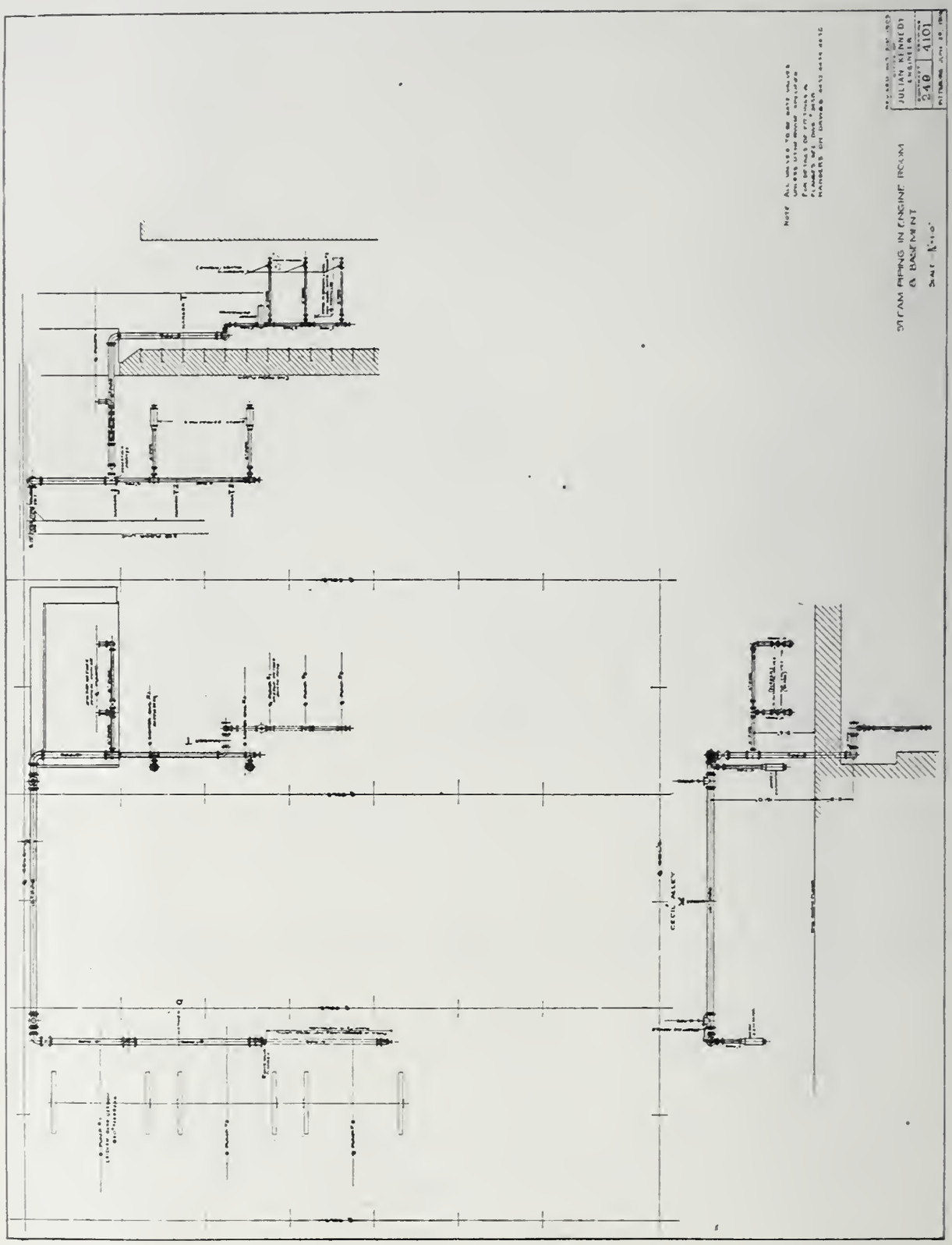


Fig. 9. Steam Piping in Engine Room and Basement.

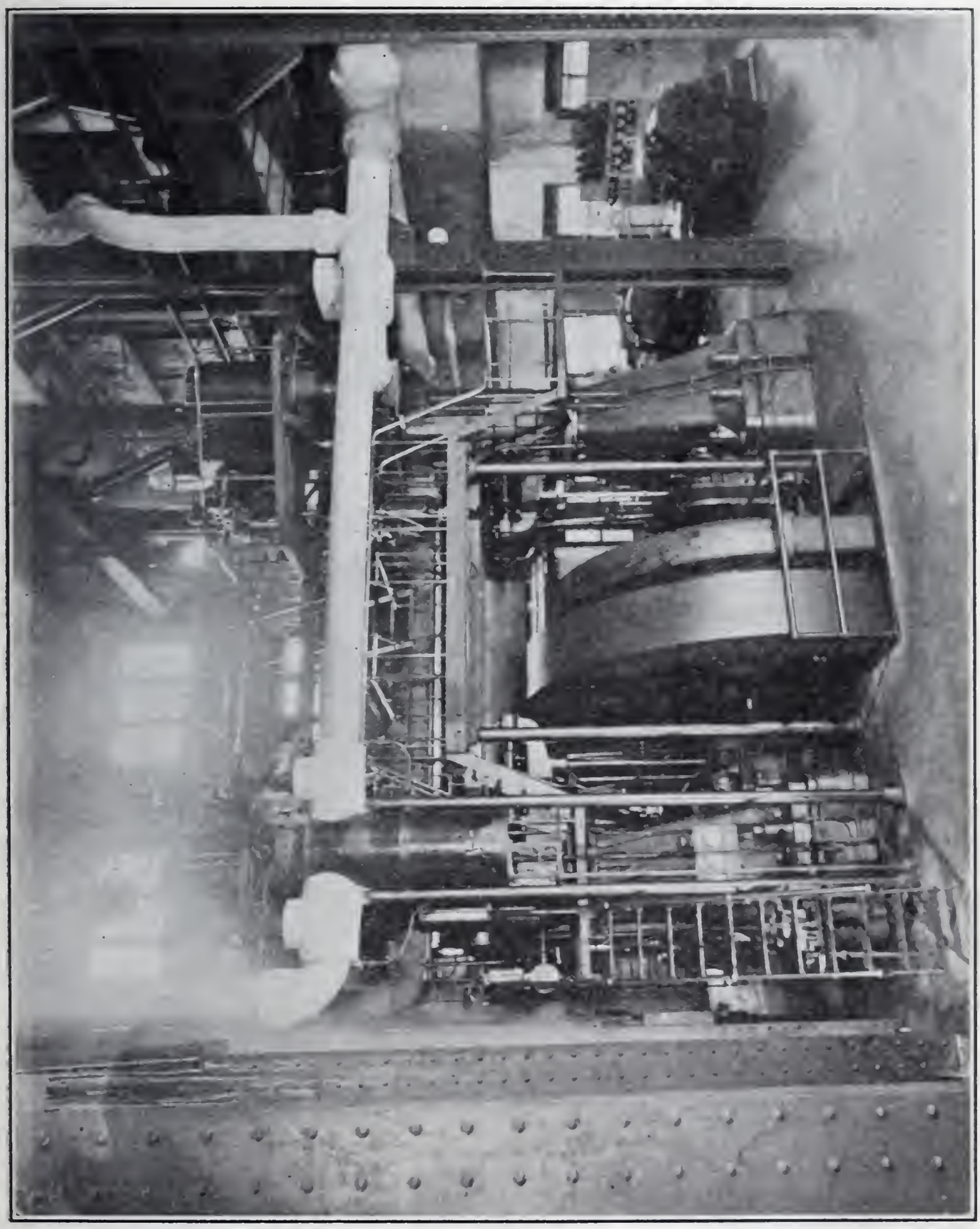


Fig. 10. Front View of Engines and Generators.

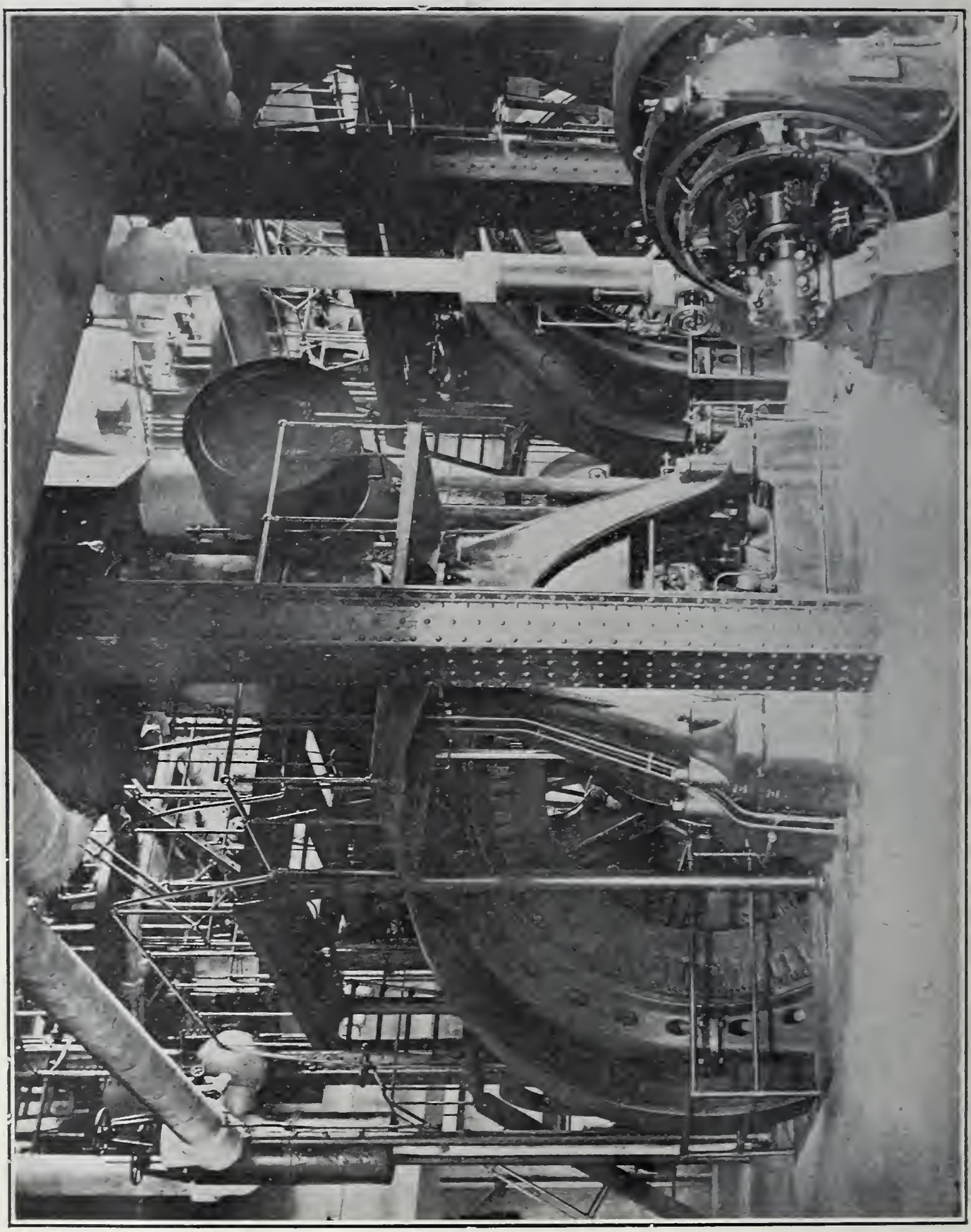


Fig. 11. View of Engine from Low Pressure Side.

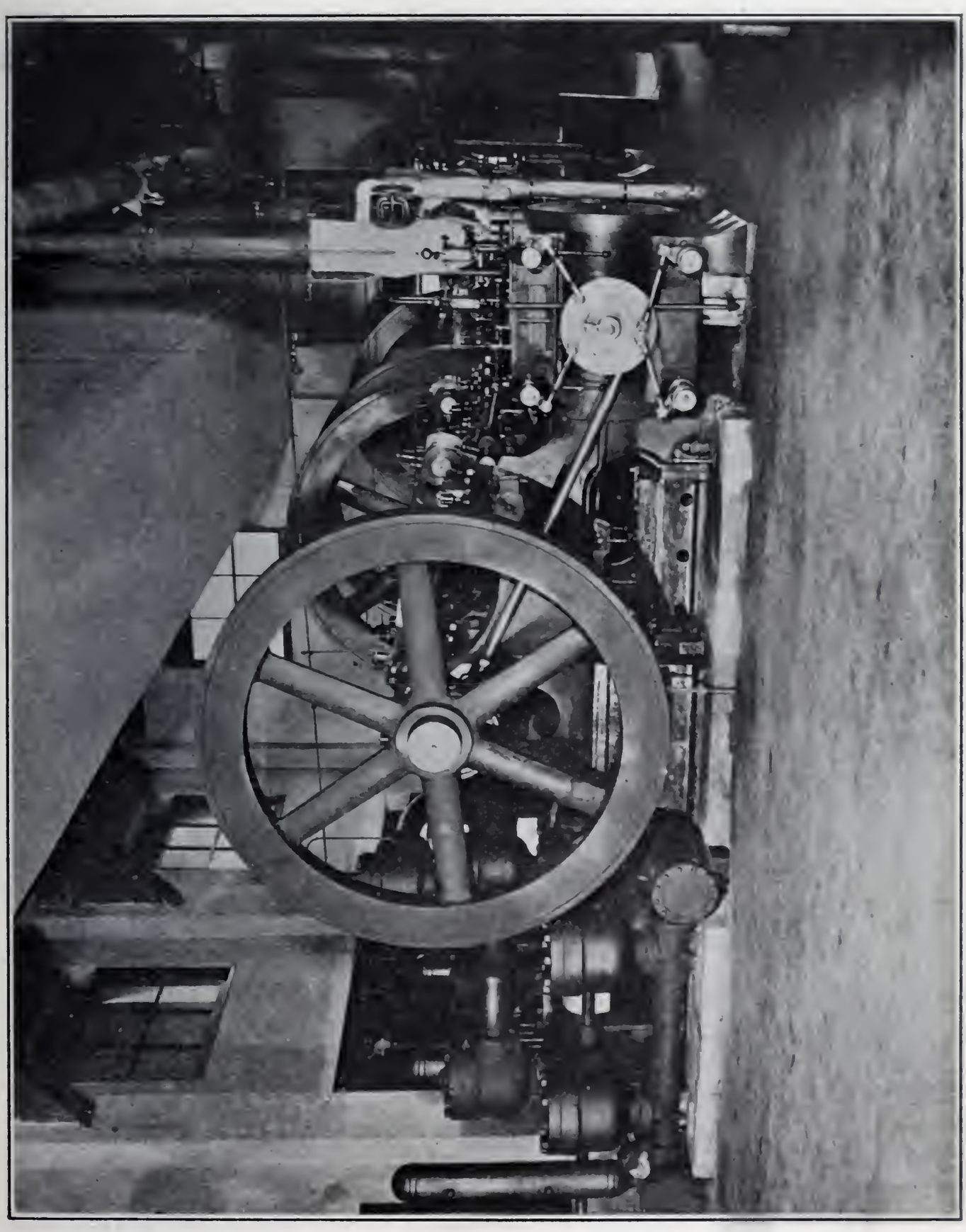


Fig. 12. The Elevator Pressure Pumps.

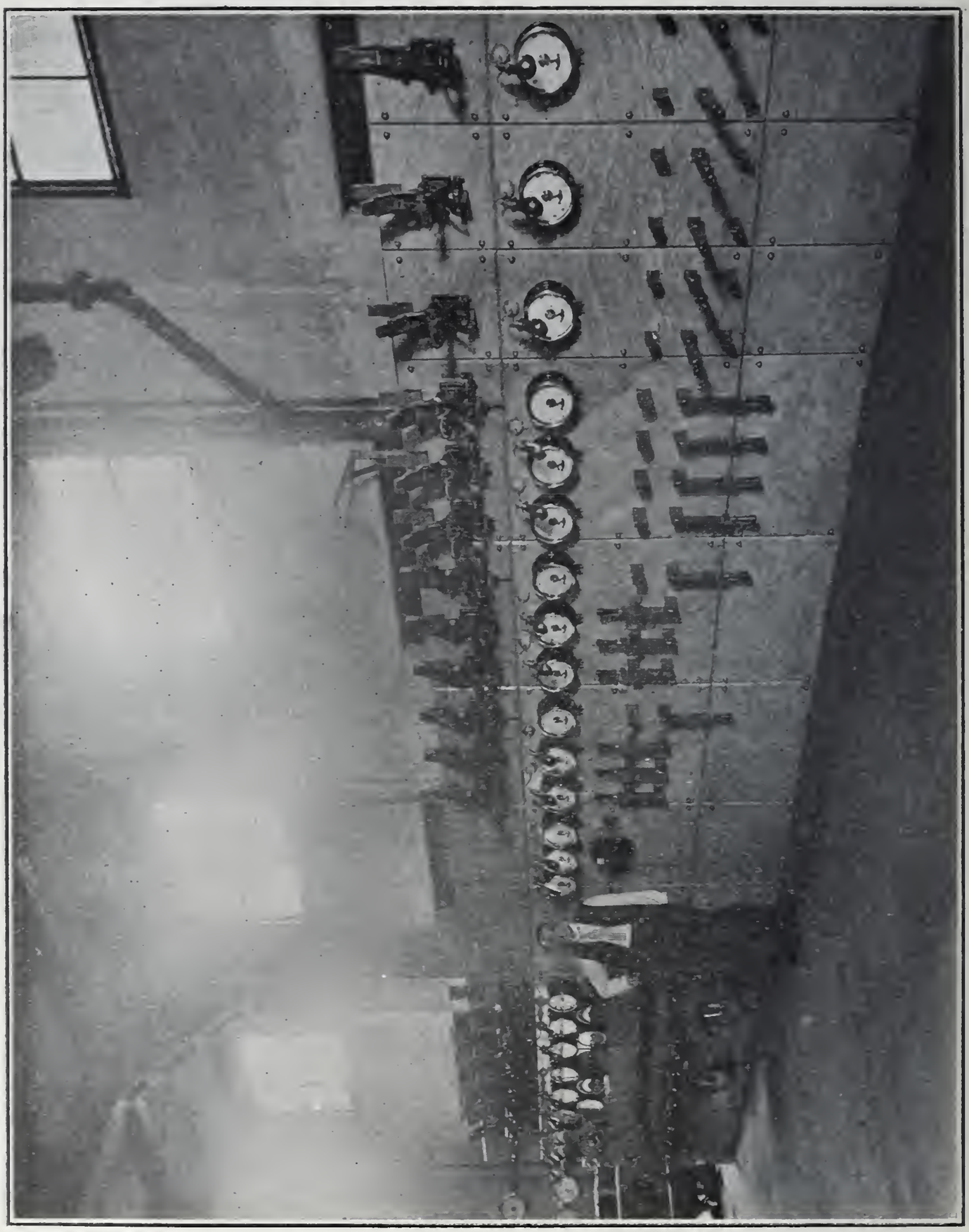


Fig. 13. Front of Switchboard.

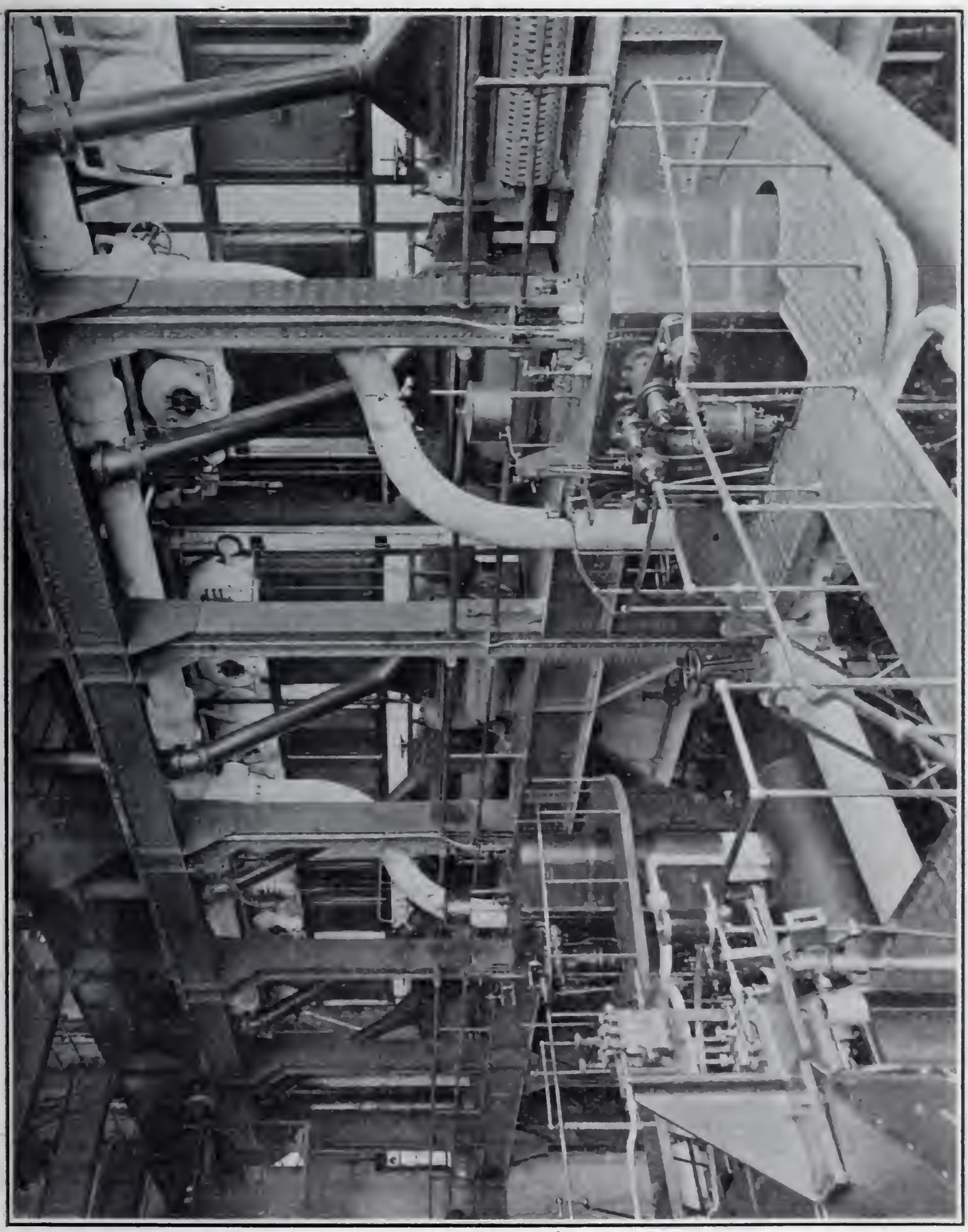


Fig. 14. View from Above the Engines—Low Pressure Side.

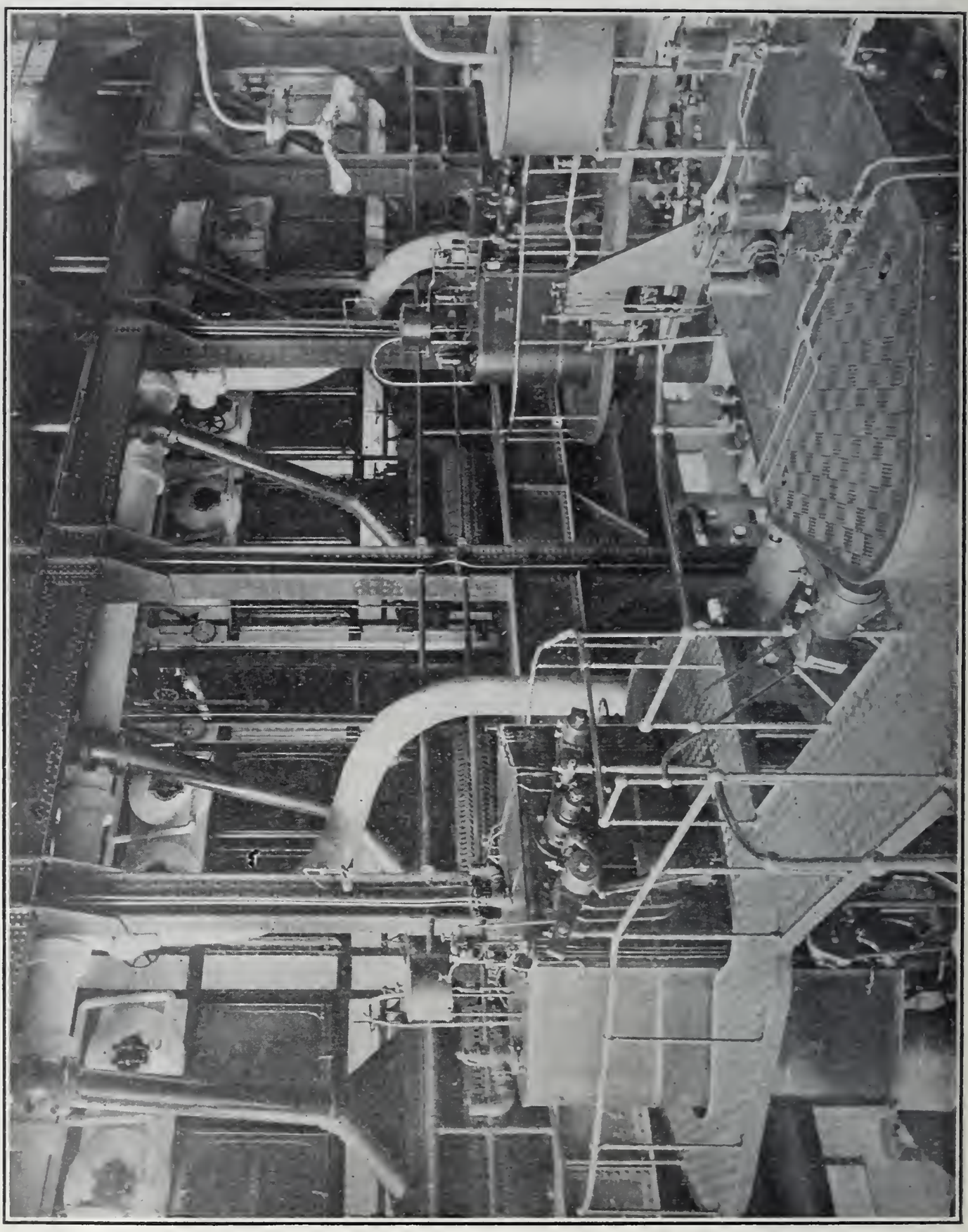


Fig. 15. View from Above the Engines—High Pressure Side.

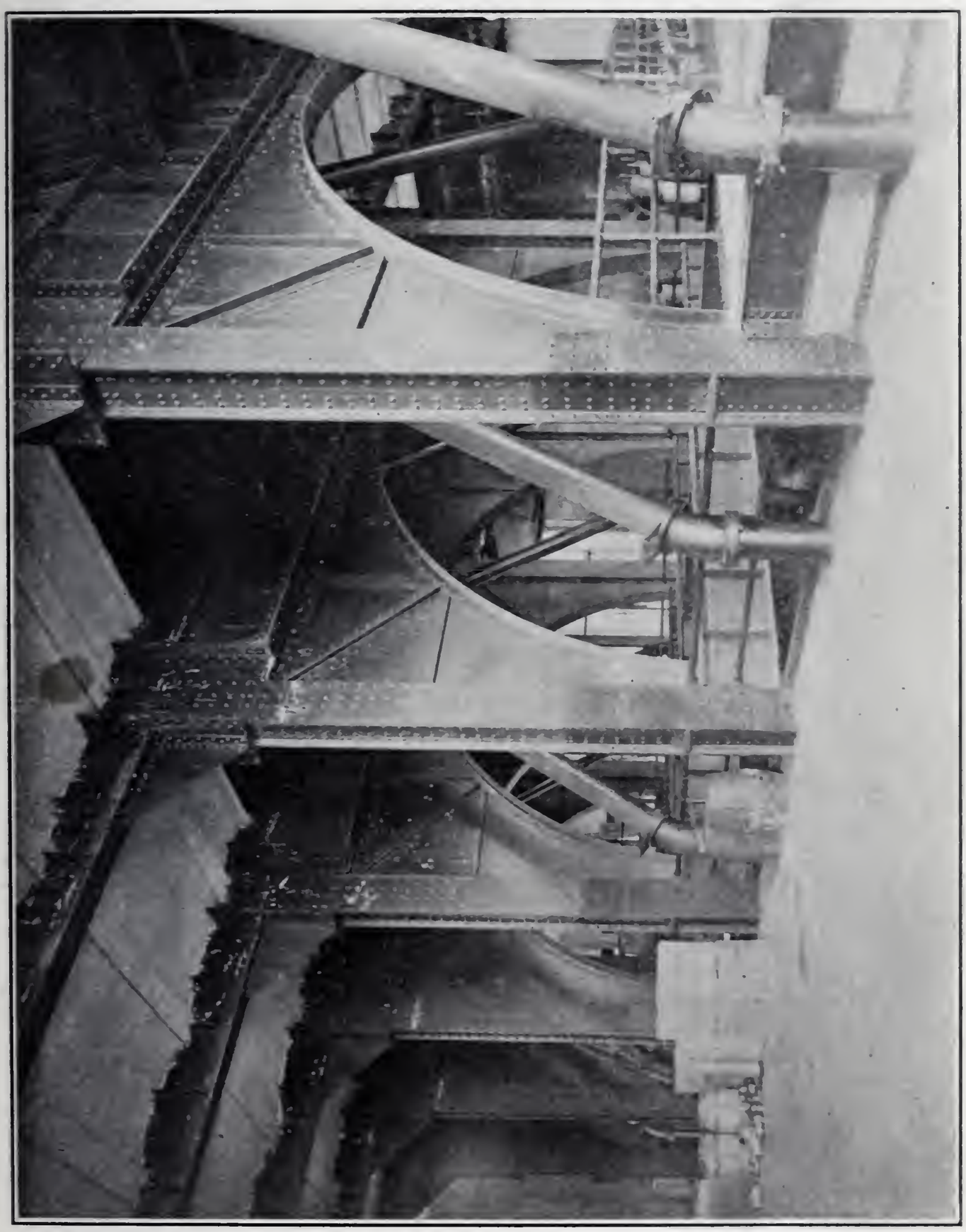


Fig. 16. Arches and Girders Under the Coal Bin.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and forty-seventh regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, September 20, 1904, at 8:15 P. M. President J. M. Camp in the chair. Fifty members and visitors were present.

The minutes of the previous meeting were read and approved.

The Board of Direction reported that they had approved the following applications for membership and presented same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
F. D. BUFFUM,	Chief Draftsman, for Monongahela Mfg. Co., h., 308 4th Ave., Monongahela, Pa.	W. H. Bailey, Wm. Allen, J. M. Camp.
WM. SHERMAN GIBSON,	Division Engineer, Pittsburg Coal Co. h., Belle Vernon, Fayette Co., Pa.	A. W. Patton, E. J Taylor. G. W. Schellenberg.
JAS. G. HEMPSTEAD,	Supt. Bolt Factories, Oliver Iron & Steel Co., Pittsburg, Pa. h., 23 Redmond St., Crafton, Pa.	F. W. Brown, Chester B. Albree, Willis Whited.

It was moved, seconded, and carried that the Secretary cast a ballot electing these applicants to membership.

The Secretary then read the report of the Committee appointed to draw up resolutions on the death of Mr. Selwyn M. Taylor, as follows:

SELWYN MELLON TAYLOR.

Selwyn Mellon Taylor was born in Allegheny, on November 5, 1862. His parents were C. C. Taylor and Eliabeth (Gamble) Taylor. Mr. Taylor's education was begun in and continued through the ward schools, and, when about 13 years of age, he entered the Pittsburg High School, where he remained four years,

leaving it to begin a practical training in engineering, which finally led to his adoption of that profession as his life's work.

Shortly after leaving school he entered the employ of R. L. McCully, civil mining engineer, and so thoroughly did he enter into his work and master its details that in about three years he was made a member of the firm, in full charge of its mining work. He continued as such until October, 1891, when he opened an office of his own.

His strong personality, keen perception and devotion to his work brought about him a clientele large in number and great in scope, and through it he undoubtedly had more to do with the successful development of the bituminous coal business in Western Pennsylvania, while connected with it, than any other individual.

After devoting his talents to others, throughout a professional career full of danger and hardship, during the greater part of which his services were not fully appreciated nor recompensed, he decided to engage those talents more to his personal advantage, with the result that in 1900 he, with a few of his friends, formed the Midland Coal Company. In connection with that company, and for the purpose of the better development of its mining properties, he located, financed and built the Western Washington Railroad. The strong position in which he placed this dual enterprise made it a very attractive investment for a very strong competitor, with the result that the property passed into the control of the latter upon terms highly satisfactory to him and to his associates.

This transaction being completed, he immediately entered into another business venture, the National Coal and Coke Company, which enterprise bid fair to outstrip, in its magnitude and success, anything he had yet attempted. He had scarcely laid the ground work in this, however, when came the ill-fated day that claimed him to his tragic death.

Being apprised by telephone of the terrible explosion on January 25, 1904, at Harwick mine, a property with which at its inception he had been connected as its consulting engineer, he repaired to the scene of the accident immediately, prepared to give all assistance in his power for the relief of the victims of the accident. Upon his arrival, there being no representative of the

State Mine Inspectors on the ground at that time, he was at once put forward as, and without hesitation assumed the responsibility of the leader in that terror-stricken crowd of willing men. At once he made such repairs to the hoisting apparatus as was necessary to make the descent into the mine possible, and with a companion, was let down the shaft upon what proved to be his last journey in life.

At the bottom of the shaft he found, and sent up to daylight, the only survivor of the one hundred and seventy-five men who were in the mine at the time of the accident. The air conditions there seemed to give him great hopes of his ability to save others, and he pressed forward in his eagerness to do so. He progressed about 700 feet from the bottom of the shaft, when he was so overcome by the foul gases of the mine that he lost consciousness, and it is thought that death came quickly to him. His was a noble deed, born in the sympathy of his great heart; the last act in a life filled with generous impulses and quiet benefactions.

He was married in 1891 to Mrs. Mary Nolan, formerly Miss Mary Zinn, who survives him.

He was elected a member of this Society on March 15, 1892. He was Chairman of the House Committee in 1897, and a member of the Program Committee in 1899. He was a member of the Board of Directors at the time of his death, having been elected in 1903.

During his membership in the Society he always evinced much interest in its welfare, and was one of its staunchest supporters. He contributed to its proceedings by a paper entitled, "Waste of Coal in Mining," which was read before the Society, September 20, 1894. He was, also, a member of the American Society of Civil Engineers.

In 1886 he framed that portion of the annual report of the Geological Survey of Pennsylvania, referring to the mining methods in the bituminous coal in the State. From 1889, by appointment of the Governor of the State, he served for four years on the Board of Examiners for Bituminous Mine Inspectors.

In closing this brief history of his life we desire to emphasize the fact that in his death this community has lost one of its best and most honored citizens; that the engineering profession

has lost one of its most brilliant members, and that his membership in this Society has wrought great honor to it.

It was moved, seconded, and carried that the report of the Committee be accepted with thanks, a copy of the resolutions sent to Mrs. Taylor and that they be published in the Proceedings.

PRESIDENT—There being no further business we will now listen to the paper of the evening.

(Paper was printed in advance in August Proceedings, see pages 371-398).

DISCUSSION.

PRESIDENT—It is easily within the remembrance of a great many of the members present when the office buildings obtained their power entirely from the city water supply. Later on, the more enlightened owners, in order to save trouble and cost, added their own boilers and pumps to run elevators. Then came the electric and the refrigerating plant, until the modern office building became a city in itself. Now we come to the next step; the power building which has been so delightfully described and which is open for discussion.

MR. SAMUEL DIESCHER—While the foundations were being built I looked at the concrete work, because it was so remarkably coarse, and I inquired what proportion of mixture they had in there, and was informed that they used one part of cement, three of sand, and as much as ten parts of gravel, and in some others I think they have eight parts of gravel. Have they not some trouble there during high water and does it not get through the concrete? I should think that would drown them, unless they pump the water out as quickly as it comes in.

MR. G. E. FLANAGAN—They do undertake to pump the water out as quickly as it comes in, and so far they have been able to do that. It only comes in when they have thirty-five feet, or something like that, in the river. They then get a high pressure of water saturating the ground around the concrete. The water has got to force its way through a very great thickness of wall, or through a very thick floor, and up to date it has not been able to do so any faster than that small pump has been able to pump it out again through the private sewer into the river.

MR. DIESCHER—The concrete in the foundation must be of a better mixture than in the arches, for I remember one rainy day, the water came through the arches almost as fast as it fell.

MR. FLANAGAN—It has already had a good test for high water.

MR. LEWIS—What is the greatest test you have had?

MR. FLANAGAN—Well, I don't know what the highest stage of water was last winter. Whatever the highest stage of water was last winter it withstood successfully. The plant was in course of construction then, and we had to build brick walls up in front of the opening in Cecil alley to keep it from flowing into the cellar, because the concrete wall was not complete at that time. At present it can flow in and fill the coal hoppers when at high flood stage and flow into the base of the freight elevator hatchway, but unless it gets higher than any recorded flood stage, it can't flow up as high as the floor and can't get into the building unless it seeps through the concrete and a certain amount will certainly do that, but probably not more freely than the small pump will take care of.

MR. DIESCHER—It appears to me that the feature of having all flanges made alike, that is to say, that they have neither raised nor recessed faces is a very good one, because it guards against mistakes in fitting them on, for it may happen that inadvertently a flange is put on the wrong end of a bent pipe, in which instance there would ensue trouble, whereas if all flanges are alike, such a possibility is excluded.

MR. EMERY—Of what material are the gaskets for the hydraulic lines?

MR. FLANAGAN—Copper, smooth copper.

MR. DIESCHER—How thick is that copper?

MR. FLANAGAN—About one-eighth of an inch.

MR. EMERY—How much clearance is there in the bolt hole in those flanges?

MR. FLANAGAN—In nearly all sizes the drills are one-eighth of an inch larger than the bolts.

MR. EMERY—Isn't that clearance going to allow those flanges to overlap enough to throw the two rounded surfaces out of line?

MR. FLANAGAN—There is a possibility of that to the extent

of an eighth of an inch, but it will not occur if they are put together properly.

MR. DIESCHER—If there is an eighth of an inch play around the bolts at the time of putting them together, they might shift. Isn't that very risky?

MR. FLANAGAN—Yes, they might shift a trifle if connected carelessly.

MR. DIESCHER—There ought to be something there to prevent that shifting.

MR. FLANAGAN—Well, up to date it has shown itself very perfect joint. Of course it is a new joint and you can readily see that it has some advantages. (Explains with sketch at blackboard.)

MR. KNOWLES—Is that joint used only on the 850-lb. water line, or also on steam lines?

MR. FLANAGAN—Only on 850-lb. water line. Not at all on the steam lines, which are all made with ordinary gaskets—no male and female joints.

PRESIDENT—Cast iron flanges, Mr. Flanagan?

MR. FLANAGAN—On the hydraulic lines all flanges are forged steel with cast steel fittings and wrought iron pipe. The pipe is threaded in the flanges and then pened in afterwards to fill the threads. On all other lines, flanges above six inches are also forged steel.

MR. LEWIS—It appears to me that the real strength of the joint is in the small dove-tail formed in the inner edge of the gasket by the projecting rounded ends of the pipe.

MR. FLANAGAN—Yes, and it is squeezed between the pipe ends.

MR. WINTERS—Would not that also to some extent prevent the lateral displacement with reference to that one pipe there?

MR. FLANAGAN—Yes, undoubtedly.

MR. WINTERS—So that if you exercise reasonable care in getting the pipes in line, the pressure in drawing them together would cause the pressure of the gasket to act to some extent in holding the pipes in line.

MR. KNOWLES—In what manner is the exhaust steam utilized for heating purposes? Directly in the steam heating system or for heating water?

MR. FLANAGAN—Directly in the steam heating system. They just bring exhaust steam to the office building and then the architect or contractor deals with it in the usual way.

MR. KNOWLES—What is done with that waste steam heat when the buildings are not heated?

MR. FLANAGAN—Then it goes to waste; for instance throughout the summer, but there is more or less demand for heat in these office buildings through the greater part of the year.

MR. NEWBURY—Is there no condenser?

MR. FLANAGAN—No.

PRESIDENT—Do they suck the steam through or depend on the back pressure to force it through?

MR. FLANAGAN—The back pressure will force it through. The plant is arranged so that it is operative at as much as five pounds back pressure.

PRESIDENT—Will that much back pressure be sufficient to supply all the offices in all the buildings it is purposed to erect?

MR. FLANAGAN—They calculate that five pounds pressure will send the steam a great distance, and through a great many small radiators. There are plants working at a considerable distance that do not work up to more than two and a half or three pounds. I do not imagine they have used anything like five pounds pressure yet on this.

MR. NEWBURY—That would be a great loss of steam in the summer months.

MR. FLANAGAN—Well, it is a loss during the summer months, but the loss then was held to be more than off-set by the saving in the condensing plant, inasmuch as we can use the greater part of the steam.

MR. NEWBURY—Do you use the steam for heating all the rooms?

MR. FLANAGAN—Yes.

MR. STUCKI—I understand the stacks are not lined.

MR. FLANAGAN—They are not.

MR. STUCKI—Do you not fear that the life will be comparatively short? I have heard parties who used plain stacks say they would not use them again.

MR. FLANAGAN—I can only say that the question of lining was taken up and very well considered, and the conclusion arrived at was to omit the lining, and that was after comparing notes with a number of people who ought to know, and who concluded that the lining was of less use to the stack, than it was a detriment to the building to put that mass of brick work up there; that it did comparatively little good to the stack. They will last nearly as long without the lining as with it. The stacks were made fairly heavy, about three-eighth inch plates where there was no absolute occasion for this thickness except to render them durable.

MR. YARDLEY—Have you any idea how long you expect them to last?

MR. FLANAGAN—Personally I don't know.

MR. YARDLEY—Well, did they make a calculation? That must have entered into it. They supposed the thing was going to wear out?

MR. FLANAGAN—I can't say that I know any number of years assigned as the limit. Engineers connected with boiler plants and work of that class seemed to consider that the life of the stacks would be so long it was hardly worth discussing it.

MR. YARDLEY—It may be here in this climate, but where there is salt air stacks go to pieces pretty fast.

MR. FLANAGAN—If the upper portion of the stack where exposed to atmosphere does show signs of failing, there is no great difficulty in restoring it. There seems to be a concensus of opinion that there is no great danger of needing new stacks on that building while most of us present are living to look at it.

MR. DIESCHER—In the sectional view of the building it is shown that the stacks pass through seven stories of rooms. Is not the heat from the stacks, particularly during the summer, such that the rooms next to them are practically useless?

MR. FLANAGAN—Those floors are for the most part large open floors, very little sub-division taking place in them, and the stacks, as noted in the paper, are 11 feet in diameter and are surrounded by an enclosure thirteen feet square, built of hollow fire-

proofing tile, which is intended to act as a non-conductor of heat and hold back the bulk of it against the stack. There is between the stacks and the wall a space for the free circulation of air.

MR. EMERY—Is there any opening in the base of that enclosure surrounding the stack?

MR. FLANAGAN—It is open free to the engine room and clear up to the roof. That rectangular space is open entirely around the stack, causing a strong draft of air. As noted in the paper the space in question was designedly arranged as a ventilating shaft for the engine and boiler floors, and anyone standing on the roof near the opening will feel convinced that it is in active operation.

MR. LEWIS—Then the stack hood would cover the opening?

MR. FLANAGAN—Well, there is practically no hood on it. There is merely a little circular apron to shed the worst of the rain and that is at a considerable height above the roof, so that it does not interfere in any sense with the passage of the warm air.

MR. KNOWLES—I have listened to this paper with pleasure, and believe that Mr. Flanagan is to be commended for presenting in such a clear-cut way so much of this unique information. Several things have come to mind in listening to him about which I would like to ask some questions. The problem of the stack has been brought up, and it does seem to most of us to be a new development; as we have thought all along, at least I have thought, that the life of steel stacks is quite short; furthermore, they are not so likely to give satisfaction in regard to draft if not lined, and it is a question whether they are not more expensive than some other types of hollow tile chimneys.

The joints on this pipe also present some interesting features and it would be very interesting to know whether that joint as shown is an advantage compared with the usual type of having the copper gaskets of the same diameter as the flanges with holes through them, and not have such a large space between the faces of the flanges which, possibly together with a clearance of an eighth of an inch may allow this copper gasket to become not concentric. At least one of the pipe flanges may move the distance of an eighth of an inch.

As Mr. Flanagan was reading the first of the paper, the thought occurred to the speaker as to whether that floor was de-

signed to withstand the extreme high water pressure and be held tight at its extreme flood, 32 feet I think. Perhaps it is meant that the water would seep through and this equalize the pressure.

In regard to the pipe upon this work, Mr. Flanagan mentions wrought iron, and I would like to have an expression of opinion as to whether they did intentionally use wrought iron, and why. I notice in one case galvanized steel was mentioned; there was probably some reason and it would be of interest to know that. In regard to the boiler, however, the stokers particularly interest me; what they accomplish, etc. The thickness of the fire which they run and whether that thickness was uniform is also of interest, then, is there any way to allow a circulation of air at the back of the fire near the bridge wall, or is there a deflector there?

I should take it from Mr. Flanagan's statements that there is a provision for using one of the in-take pumps for the supply for the building to pump back through one of the lines. Is it expected that the lines may become filled with sand and thus become stopped up? Has that been done at all during the last flood, and is the method of pumping back entirely successful?

The fact that no condensers are used is of interest and possibly in this place where coal is so cheap, it does prove to be the best, but it certainly is an unique departure that there should be such a vast amount of steam wasted in all but cold weather; there is undoubtedly trouble in using condensed steam from the units over again. Can Mr. Flanagan tell us whether those grease traps are successful?

The only other thing that occurred to me is what is the velocity for which these steam lines are designed?

Mr. Flanagan—I think I had better get a list of those questions. We consider that for the span of that floor, it will stand it as an inverted concrete arch, if you refer to the upward thrust of the water. The span is in the neighborhood of 21 feet. The columns are 32 feet eight inches centers, and the spread of those walls on one side would be from the center of the column four feet nine inches, on the other side six feet three inches; the sum of these taken from 32 feet would leave you the span of the arch forming the floor. Answering a question which has been asked to-night, I may say there is no steel reinforcement, nothing but

concrete. Now we go backwards to another question. We considered that wrought iron would withstand the effects of corosion much better than steel, and especially in the warm water line, where we did not want to be liberal enough to put in the brass, we stipulated and took care to get wrought iron.

MR. KNOWLES—How can you be sure to obtain wrought iron in this district?

MR. FLANAGAN—Well, we have to trust something to the manufacturers. I believe it is possible to get wrought iron pipe from people who do not make steel. I feel safe in that. I don't mean to lay stress on that being galvanized steel, but simply that the pipe laid in the ground returning from the Bessemer building was cast iron, and the short length of that main inside the building was all lap-welded pipe, galvanized inside and out.

MR. DIESCHER—Do you have any trouble with the pumps?

MR. FLANAGAN—No. We used the blow back in starting to clear out those in-take lines, and I have not heard that they have had any occasion to use it since.

MR. KNOWLES—How close is the screen mesh on the end of the in-take?

MR. FLANAGAN—The screens are of 5/32″ bronze wire, 7/8″ mesh. The screens are double, one behind the other, and can readily be removed and cleansed.

MR. DIESCHER—If you got the screen clogged with high water, how would you get it?

MR. FLANAGAN—The screens are very large and very ample, and if by far the greater part of both screens were covered they would still draw sufficient water to run the plant. In addition to the holes in the screen, the cover plates over the in-take are provided with slots about 3/8″ wide by 3″ or 4″ long giving an aggregate area nearly equal to that of one of the pipes.

MR. KNOWLES — In case you use that 16″ line only, for the large supply of the building, will the velocity of that line be enough to scour all of the material which comes into the inlet of that line straight through into the building, or will it lodge in the pipe?

MR. FLANAGAN—We do not think, that for many years, those 16″ pipes will be taxed to their capacity, so that for the present

at least, and probably for a long time to come, the velocity in the pipes will be very low, and the sediment can deposit in them and then the provision for blowing them out will come into play.

PRESIDENT—If your maximum in the flow-in won't move the sediment inward, I can't see how the maximum outflow will move it outward.

MR. FLANAGAN—No, but we can blow it out at 150 pounds pressure. In that 16″ pipe we can turn the discharge of one pump into the suction side of the other and blow 150 pounds pressure through it. The ordinary pressure is sufficient to force the water to the top of the Bessemer building. In this in-take pump the out-let is, I think, 14″ diameter on the discharge side which may be blown back into the 16″ line at a pressure of 150 pounds. Possibly it might exceed that, but that is the rated working pressure of the pump.

About the stoker, I believe that those chain-grate stokers give their best service when they are not forced above their capacity, and when you can keep a rather heavy fire on and not burn it too fast, so that you have a thick bed of fuel on the grate.

MR. KNOWLES—Still, a heavy bed of fire left so that air will not get through freely.

MR. FLANAGAN—Well, they claim that air does get through, and that is the greatest claim the opponents of the chain-grate make against it. I think a bed of fire six or eight inches thick can be maintained, and it is largely the fault of the attendant if good results are not obtained.

MR. EMERY—Can't you raise the temperature of any draft that does get in there?

MR. FLANAGAN—I don't know that I clearly understand the question.

MR. EMERY—I have seen some fire boxes built with a shield practically the same as a brick arch in a locomotive, which takes the cold air when it comes in through the thin fire at the front and passes it back over the hottest part of the fire before it can enter the flues.

MR. FLANAGAN—There is nothing of that nature in these furnaces.

MR. EMERY—That has been followed out quite extensively in steam locomotive construction. Where there is a direct draft into the flues, they put a brick arch across the fire-box about the middle, extending to within a few inches of the flue sheet.

MR. KNOWLES—What is the price of that joint compared with the ordinary flange joint?

MR. FLANAGAN—I cannot tell you the price of anything connected with the building.

MR. EMERY—What is the advantage of placing a copper gasket 1/8" thick in there? A copper gasket in that style of joint requires to be stiff and reasonably strong. Wouldn't it be stronger if thinner?

MR. FLANAGAN—It would not. You want it so that it will maintain its shape while handling. One-eighth of an inch on those large 10" lines is not a very thick gasket under those conditions.

MR. DIESCHER—If the copper is thick and soft and it is compressed, the ridge of the flanges will enter deeper than if it is shallow or thin.

MR. SCHATZ—In deciding the size of units that are installed for electrical purposes, I would like to know in what way they reached the conclusion to put in 1,500 horse power units. I should surmise that these engines are operating very uneconomically since there does not seem to be very much load for them.

MR. FLANAGAN—The plant is aimed at a little distance into the future in every respect. The expectation is that it won't be a great way into the future before there will be a number of buildings of the character and capacity of the Bessemer building, or probably of much greater capacity there to draw light, heat and power from the central plant, and I believe the work is even going on now.

MR. NEWBURY—Do I understand there are two water systems, one at high and one at low pressure?

MR. FLANAGAN—There is a general water supply for all purposes except drinking, that is for lavatories and boiler rooms, and the general circulating system at 150 pounds. The hydraulic system which does nothing except operate the hydraulic elevators—the pressure side of that system is 850 pounds. On the discharge

side it is between 75 and 80 pounds. That is, the elevator cylinders exhaust against a back-pressure of almost 80 pounds. Then there are the large valves which operate the cylinders of the elevators, and which, in turn, are operated by smaller valves which draw the water from the 80-pound line, and the discharge from those valves is at atmospheric pressure into an open tank. It is then pumped up into the open tank on the roof, and finally comes back into the elevator line, because the elevator pumps draw their suction partly from the roof tank. That is the surplus. When the water comes back from the elevator cylinders faster than the pumps are taking it, the surplus goes up into the tank on the roof. Then when the pumps are taking water faster than it goes back to the suction line, they draw water from that roof tank. So you have three water pressures, the general water supply, 150 pounds, the hydraulic water line, high pressure 850 pounds, and the return from the cylinders, 80 pounds; then, in addition to that, you have the drinking water from the artesian well.

MR. SCHATZ—Mr. President, Mr. Flanagan has not made that matter clear about the units. It seems to me the night loads are very small when taking into consideration the large units, and it further seems that it would take a great many buildings the size of the Bessemer office building to make a fair night load for these 1,500 H. P. units, and I should think it would be rather expensive operation.

MR. FLANAGAN—I would have to answer that by my guess regarding it, as I did not determine the units. But I think the idea prevailing with the owner of that property is what we have discovered in rolling mills; that you can build a rolling mill today and if you don't build it a good deal better and heavier and stronger and more liberal in every way than the circumstances seem to call for, in five years from now you will be antiquated. They seem to be looking ahead for a much larger call for light and heat from the power plant than what we would figure on. In every way the building is made on that scale. To provide for more than we think will be necessary.

MR. STUCKI—If I understand this right, it is not a question of the size of the plant, but one of sub-division.

MR. FLANAGAN—Well, then, beyond that the only thing I can

mention is the desire to simplify matters by having the large units instead of a number of small ones, and to produce the largest possible output from the given floor space. The night load is something that is rapidly increasing, and the end is not yet in sight. Anyone who doubts this need only compare the Pittsburg of the present with the same city not more than six or eight years ago. The use of light by tenants for advertising purposes alone is going to constitute an important factor in the night load of the future. I really do not know as yet what demand they are going to have for direct current, other than the exciting of the fields of the generators. We did use the direct current for lighting purposes before we had the main engines in operation. As noted in the paper there is room for the installation of additional steam driven direct current units, and also there is the possibility of transforming some of the surplus alternating current by rotary transformers in case direct current is wanted.

MR. KNOWLES—Do you run a refrigerator plant there?

MR. FLANAGAN—None at all.

MR. SCHATZ—I would like to ask Mr. Flanagan a few more questions regarding the steam used for heating purposes. Is it passed through an expansion tank after it leaves the engine on its way to the buildings, in order to remove any water or oil, and also whether live steam is passed through an expansion tank or through a reducing pressure valve and direct into the heating mains. I would also ask him if the vacuum system principle is used on returning the condensation from the radiators. Another question is, I notice there is very limited provision made for furnishing direct current for purposes, for which direct current is most generally used. There have been, no doubt, inquiries for this current. I understand that it is possible to furnish some direct current from the exciter units, but in this way they are limited and then it is not always good practice to do so.

MR. FLANAGAN—It is easy to install some more direct current machinery there. They have got two direct current generators. Of course, they can use one as an exciter, and they can use the other for any other purpose they see fit, having it is a possibility to fall back on if anything occurs to the one used as an exciter. And if the demand increases there is room for additional

small units of that kind. I don't know that I followed the question regarding the exhaust steam, but instead of answering the question I can describe the conditions that exist there. It is simply that they exhaust right from those engines into 18-inch pipes which are collected very quickly into a 24-inch one, and, after a short travel, into a 30-inch one; and from the 30-inch line a 20-inch branch, I think it is, now runs over to the Bessemer building. There are no features to it, except that there is an exhaust muffler and grease separator, and there is also a back pressure valve on the 30-inch line to force as much of the steam into the steam radiators as is required; that is, they can regulate the valve until the back pressure is sufficient to force it into the farthest radiators and the piping is arranged so that only a part of the smaller machinery need be on the back pressure line When there is only a small part of the steam taken for heating, the bulk of the machinery can be exhausting free to the atmosphere while some of the smaller units are operating under the back pressure. Then when the winter sets in the necessary valves can be operated until all the steam in the plant is behind the back pressure valve. I have forgotten what is the length of the 20-inch pipe; I think it is about 300 feet. There is just one slip-joint. There is no vacuum system.

MR. KNOWLES—What is the velocity of the steam in the high pressure line and also in the heating line?

MR. FLANAGAN—I think the velocity would be about 6,000 feet, if I recall it, in case the engines were running up anywhere near their capacity, and my impression is it would be somewhere around 4,000 feet exhausting.

MR. JAMES—Mr. President, I think the subject here is of a great deal of interest to those who have been following the development of power in large buildings. The power building we have here in Pittsburg is not only a departure for this city, but there have been very few plants of this kind put in anywhere. I think in following Mr. Flanagan's paper the point that most impresses itself upon one is the fact that the apparatus that has been put in this building is what we might call classical. There have been very few new things of a large nature tried there, and yet they have looked forward into the future with a great deal of their

apparatus, and I think they were very wise when they made such large provision for alternating current and very little for direct current. Pittsburg is the home of the alternating current industry; the Nernst lamp and the Schupp electric motor is only a matter of a very short time. The single-phase induction motor is now on the market, and for all the largest power purposes the polyphase, the present power, is very satisfactory. It is only on intermittent speed service that the direct current motor is in demand, and then it requires either shunt-field regulation or else resistance, the latter often very powerful. The alternating current motor is susceptible of a plunger regulation, which gives you a much better control over it.

It was moved, seconded and carried that a vote of thanks be extended to Mr. Flanagan for his very interesting paper.

Motion to adjourn seconded and carried.

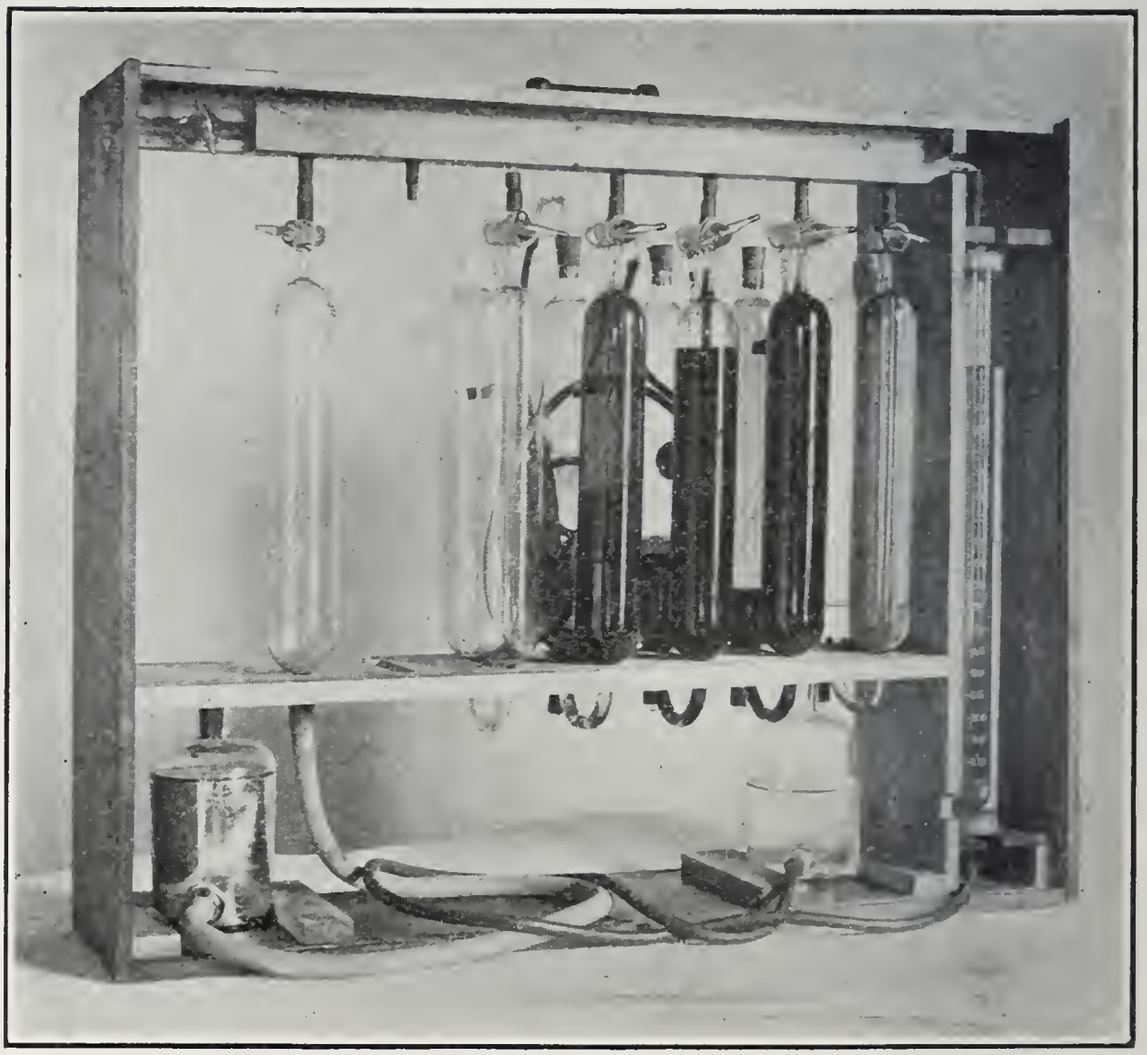
C. W. RIDINGER, *Secretary.*

AN IMPROVED GAS APPARATUS.*

BY J. E. BABB.

The drawing and photograph represents some new features of the Orsat Apparatus. In general design is quite similar to it.

For purposes of making a greater number of determinations and greater variety of gases six absorption tubes are employed, these being large enough to accommodate 250 C. C. of absorbent solution in each tube. An explosion tube is included.

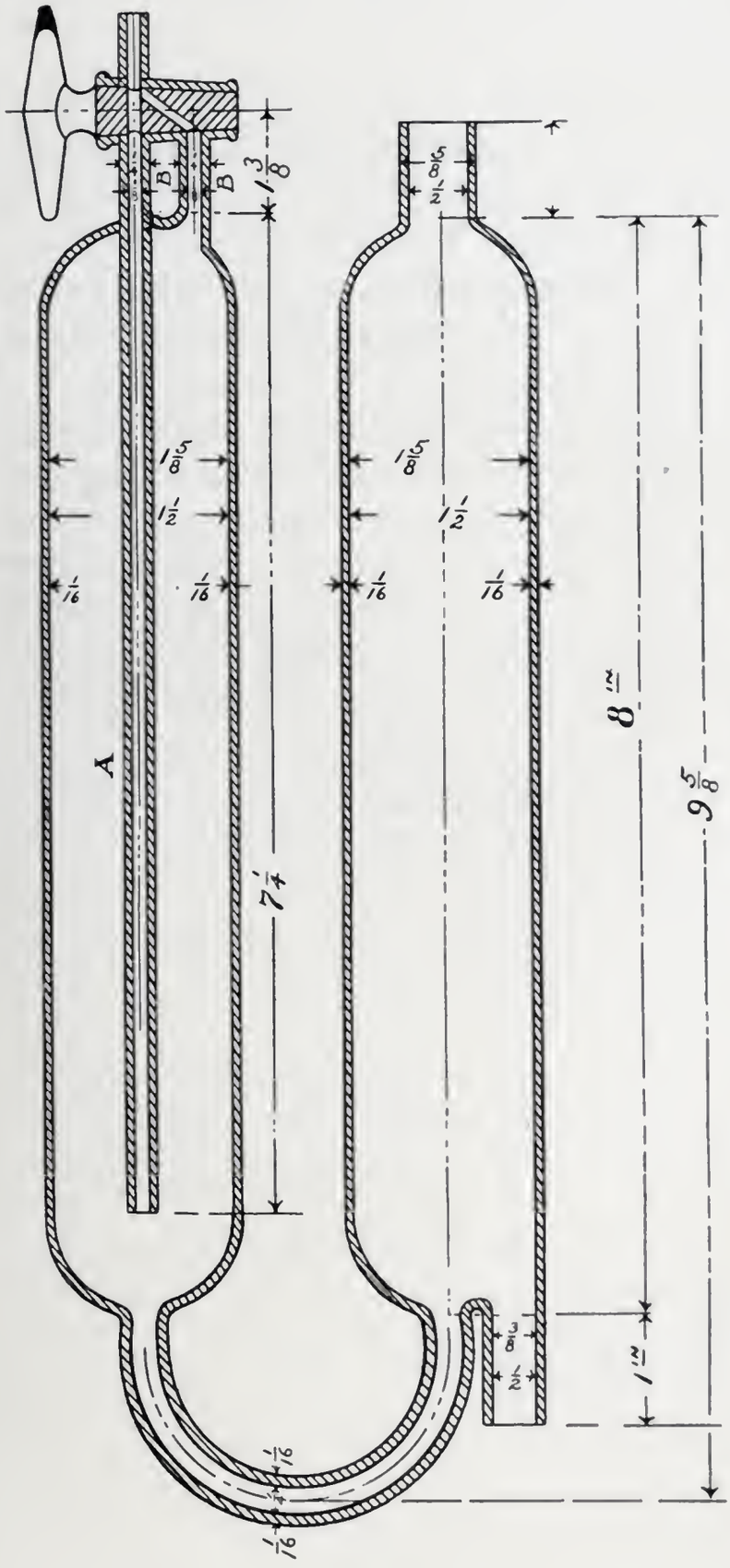


An Improved Gas Apparatus.

The box is made to contain besides the tubes two (2) dry cell batteries, one induction coil, and an oxygen tank. Two leveling bottles, one for water to confine gases, and one for

*Paper read before the Chemical lecture at their September meeting.

mercury to confine gases for explosion. This necessarily makes the apparatus large. But at this it is only the size of an ordinary dress suit case.



Gas Testing Apparatus.

The principal feature of the apparatus is the bubble tube shown in the cut. It consists of two large tubes, back and front. The front tube consists of a capillary tube (A) placed inside of the large tube, and connected with a three way cock and at the top of large tube.

In use, the three way cock is engaged only with the capillary tube (A). The gases then bubble up through the absorbent solution. To turn the gases back into measuring burette, the three way cock is engaged with both the capillary tube (A) and exit tube (B). The gas passes out through (B), the solution rising up in the large tube and capillary tube (A) at the same level, the analysis being otherwise conducted as in the Orsat. By bubbling the gas through the absorbent solutions in this manner, a more rapid and complete absorption of gases is obtained, and is superior to absorptions by contact and shaking, one passage of the gases being sufficient for complete absorption.

A rapid analysis for gases for gas engine control can thus be made in 12 to 15 minutes, including analysis for carbon dioxide, oxygen, carbon monoxide, hydrogen and methane, and ethylene.

The idea of bubbling the gas through the solutions has been suggested by many, and has been applied, but not in so convenient a manner.

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held at the Society's room, 410 Penn Ave., Pittsburg, Tuesday, September 27, 1904.

The Section was called to order at 8:30 P. M. by the chairman, Mr. Frans Engstrom, there being 22 members and visitors present.

Subject selected for discussion at the October meeting: The Phipps' Power Building, Pittsburg, Pa.

The subject for discussion was: Modern Progress in Masonry Construction.

The following papers were read:

"Occurrence of our Building Stones." By F. Z. Schellenberg.

"Mortar." By Joseph A. Shinn.

"Brick Masonry." By L. C. Weldin.

Remarks were made as follows:

"Foundations." By Robert A. Cummings.

"Testing Concrete and Stone." By Geo. T. Barnsley.

The remarks of Mr. Barnsley were illustrated with lantern slides.

The discussion was participated in by E. K. Morse, W. Whited, G. E. Flanagan and others.

A vote of thanks, was tendered to the writers and speakers of the evening.

On motion Section adjourned at 10:30 P. M.

WILLIS WHITED,
Secretary Structural Section.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and forty-eighth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, October 18th, 1904, at 8:17 P. M. President J. M. Camp in the chair. Fifty-six members and vistors present.

The minutes of the previous meeting were read and approved.

The Board of Direction report that they have approved the following applications for membership and present same to the Society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
RODGER D. DeWOLF,	E. Engineer, with W. E. & M. Co., h., 508 Rebecca St., Wilkinsburg, Pa	S. M. Kintner, P. E. Lincoln, W. A. Dick.
WM. E. DICKSON,	Chemist, American Window Glass Co., Monongahela, Pa.	G. P. Maury, R. W. Bridge, R. Linton.
R. L. FRINK,	Electrical Engineer, American Window Glass Co., h., Belle Vernon, Pa.	G. P. Maury, R. W. Bridge, R. Linton.
WM. W. LANG.	Special Representative W. W. Lawrence & Co., Pittsburg, Pa.	E. J. Moore, T. E. Doyle, C. D. Wettach.
WM. MEYN,	Manager of Branch Office, Schutte & Koerting Co., 691 Times Building, Pittsburg, Pa	N. C. Wilson, J. W. Landis, V. Beutner.
FREDERICK H. MILLER,	Draughtsman, City Hall, h., 2525 Mahon St., Pittsburg, Pa.	A. E. Duckham, L. E. Vierheller, C. A. Finley.
GEO. NEWBURY,	Draughtsman, Jones & Laughlins Steel Works, S. S., Pittsburg, Pa.	J. L. Klindworth, G. E. Flanagan, A. E. Hoerr.

WM. S. RALSTON,	Salesman, Chaplin-Fulton Mfg. Co., Pittsburg, Pa.	L. B. Fulton, Chas. Worthington, A. B. Hine.
EDW. H. RODGERS,	American Tin Plate Co., h., 118 Irvine Ave., Sharon, Pa.	Geo. C. Mors, M. W. Hogle, S. B. Ely.
G. B. ROSENBLATT,	E. Engineer, Westinghouse E. & M. Co., h., 4924 Center Ave., Pittsburg, Pa.	S. M. Kintner, H. D. James, J. S. Peck.
JOHN S. SLOAN,	Superintendent, of Coraopolis Light Plant, Coraopolis, Pa.	W. M. Judd, H. D. Lufkin, P. A. Young.
PAUL S. WHITMAN,	Assistant Structural Engineer, Riter-Conley Mfg. Co., h., Ingram, Pa.	L. F. W. Hildner, F. S. Rice, G. H. Sikes.

PRESIDENT—I regret to announce the death of one of our oldest members, Mr. Arthur Kirk, an account of whose death you have probable all read in the papers. It is the custom to draw up resolutions on the death of our eminent members and I will appoint on that committee, Mr. Samuel Diescher, Mr. Chas. Davis, and Mr. F. Z. Schellenberg. It is also the duty of the President at the regular October meeting to appoint a committee to nominate officers for the Society for the ensuing year and report at the regular November meeting. I have selected for the Nominating Committee, the last five presidents of the Society, namely, Mr. Scott, as Chairman, Mr. Albree, Mr. Fisher, Mr. Bole, and Mr. Lewis.

MR. PHILLIPS—Mr. Chairman, our Society stands almost alone among the engineering societies, in not having its transactions in such shape that the particular articles are accessible. I think we ought to have an alphabetical list printed of all papers read before the Society since the beginning, and I move that the Secretary be requested to provide for a separate volume to include an alphabetical list of our papers: that is, an alphabetical index serving to show where the articles can be found, the dates of them, etc. I also move that hereafter an alphabetical list of each year's transactions be printed and added to the volume for that year.

PRESIDENT—There is a contents sheet printed with each volume.

MR. PHILLIPS—Yes, but not an alphabetical list, so that it is very hard to find an article that may have appeared a few years ago. Of course this would require considerable work, but I move that the Secretary be requested to take the matter up and have it done.

PRESIDENT—That would be a rather small pamphlet, I would imagine. Would it not be advisable to add to that an alphabetical index of the authors?

MR. PHILLIPS—Yes, it might be better to have the authors' names appear in alphabetical order also. Of course we can find the article more quickly by either looking for the author's name or the subject in the alphabetical order. These two could be combined.

MR. DIESCHER—If I understand the Professor right, there is to be a list according to the titles of the papers read and in the same volume, a list, alphabetically arranged according to the names of the authors. That would be proper because somebody might remember that a member read a paper on a certain subject without knowing exactly what the title of the paper was. On that account, both should be alphabetically arranged.

MR. ALBREE—Mr. President, I have had occasion to refer to the transactions of the American Society of Mechanical Engineers, and they publish from time to time, every few years, just such an index as Prof. Phillips speaks of, and they do it in a rather broad way. For instance, supposing there are five papers on the subject of Springs; instead of heading each one alphabetically with the particular word the title happens to begin with it is put under the subject of Springs, and under that a sub-heading giving the title of the paper. Then there is also the alphabetical list. I think we might use that particular set of indexes as a model to go by, because you can find anything you want very easily.

MR. PHILLIPS—The list should be as complete as possible and should show all possible details, giving a complete alphabetical arrangement of all the papers and discussions that have come before the Society since it has been organized and at the

same time the names of authors, so that the articles could be found in the shortest possible time.

MR. FLANAGAN—Mr. President, this seems to be a good year for that, as I believe it marks the 25th anniversary of the Society. That would be a land-mark for the year.

MR. DIESCHER—I think it would be better to appoint a committee. Two or three could take this matter up and before it goes to the printer, it should be brought before the Society so that if any changes are to be made they can be put in.

MR. ENGSTROM—I am very much surprised to hear this motion made this evening for the reason that a very similar motion was up before the Board on Saturday evening. I am very glad to hear so many take an interest in it, and I hope the motion will prevail.

Motion carried.

MR. CUMMINGS—Before that paper is read, I would like to raise a question. I hold in my hand a clipping from a Pittsburg newspaper, handed to me on my return to Pittsburg yesterday, and it contains one of the most scurrilous articles I have ever read. Reference is made to Major Sibert, who is a member of the Society and on one of our committees. Of that I have nothing to say, but there is an article in the paper which refers to the filing of a brief in the office of the Secretary of War, Washington. You have doubtless all read this, therefore it is unnecessary for me to read it now, but I want to direct the attention of the Society and the members that are present to the fact that this Society has been drawn into this unfortunate dispute in the fact that it says that Major Sibert procured an invitation to read the address before the Engineers' Society of Western Pennsylvania, which he did at its meeting on September 23rd, 1902. I think it would be well to know how he procured that invitation. I would like to have a committee report at the next meeting and I ask that you shall appoint one.

PRESIDENT—The object of this committee is to investigate how he procured this invitation.

MR. R. A. CUMMINGS—This brief that I have just mentioned, states that somehow he procured an invitation from the Engineers' Society of Western Pennsylvania, to read a paper,

and to my mind that conveys a questionable way of procuring an invitation to read a paper. I would like to see some light thrown on this subject. I think it needs some defense. I think this Society needs some defense in the matter. It is a public question, not a private one.

Motion seconded and carried.

PRESIDENT—I will appoint on that committee, Mr. Morse, Mr. Lewis, and Mr. Diescher. We will now have the pleasure of hearing Mr. Pearson on the "Great Raised Beaches."

Mr. Pearson then delivered a very interesting lecture on the geological formation of what he termed the great raised beaches, meaning the horizontal indentations or lines found at certain elevations on sides of hills and mountains throughout the Eastern and Western Hemispheres, and supposed to have been the shore lines of ancient oceans. He showed how these beaches at certain points in America correspond, as to their elevation and general formation, with similar beaches in Europe and Africa, indicating that they were the outer edges of the same gigantic body of water. By a series of systematic deductions, Mr. Pearson endeavored to prove that the one-time generally accepted theory of the drifting formation of coal is the correct one, and that the present prevailing theory that coal beds are the result of repeated deposits, such as decayed forests, is a mistaken one. These coal deposits according to Mr. Pearson were formed at the time of ancient floods, and he also attempted to prove that these floods were the result of the rapid liquidation or melting of large glaciers then existing throughout the greater portion of the Northern Hemisphere. These waters carried immense quantities of driftwood and other natural substances into the then valleys, or depressions in the land, where it was deposited and thousands of years later found in a carbonized state, or as coal.

Mr. Pearson also stated that by the use of his system of charts (which he exhibited) showing minutely the location of these ancient beaches, he could, and has, determined the location of large coal deposits, without ever having been within hundreds of miles of the actual vicinity of the coal, and fixed its boundaries

to within a few feet of what they were afterwards found, by survey, to be.

Mr. Pearson ended his lecture with a statement of his efforts to obtain official recognition of his theory and having exhausted all his own financial resources, he is desirous of obtaining assistance of the Carnegie Geological Institution at Washington, D. C., but up to date they have refused him a hearing. He has been advised to lay the matter before the various engineering societies of the country, and stated that the Detroit Engineering Society had appointed a committee to assist him in getting the matter before the Carnegie Institute. He asked that this society do the same.

After an extended discussion of the several points in Mr. Pearson's lecture, which was participated in by Messrs. Camp, Diescher, Schellenberg, Flanagan, and others, Mr. Diescher made a motion that the Engineers' Society of Western Pennsylvania join the Engineers' Society of Detroit in requesting the Carnegie Institute at Washington, to give Mr. Pearson a hearing so that he can thoroughly explain his theory; which motion was seconded and carried.

CHARLES W. RIDINGER,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held Thursday evening, October 20, 1904, with the Pittsburg Section of the American Chemical Society, at the Society's Home, 410 Penn Ave., Pittsburg, Pa.

Chairman Walters presided.

The Committee for the Nomination of Officers of the Society for 1905 was appointed as follows: Dr. F. C. Phillips, Dr. Karl Stahl, Mr. H. Ely Myers; to report at regular meeting in November.

Chairman Walters reported that arrangements had been made for the visit of the Section to the Ward-Mackey Bakeries, to take place on the 27th inst.

The paper of the evening, Colorimetric Determination of Phosphorus, by Mr. Thomas E. Hewitt was read and discussed by a number of members.

General discussion of current literature, led by Mr. Walters, followed.

The Chairman announced that the next meeting of the Society would be held at the works of the Nernst Lamp Co.

No further business, the Society adjourned to meet Nov. 17th, 1904.

Respectfully submitted,

GEO. P. MAURY, *Secretary.*

COLORIMETRIC DETERMINATION OF PHOSPHORUS.

BY T. E. HEWITT.

The color given on passing hydrogen sulphide into an alkaline molybdate solution, seemed favorable, for a colorimetric determination of molybdenum and indirectly of phosphorus.

Among the things that might influence the color given, are: 1. Sodium hydroxide in excess. 2. Degree of saturation, by hydrogen sulphide. 3. Effect of air. 4. Comparative effect of color produced on using an alkaline solution of molybdic acid, on one hand, and a solution of yellow precipitate on the other. 5. Permanency of resulting color. 6. Best method to dissolve the yellow precipitate. 7. Delicacy of the reaction, and effect of dilution on the comparison of the colors.

Of various vessels tried in which to compare the colors, bottles, two inches square, of a capacity of twelve ounces, were selected. These bottles allowed of sufficient depth to compare the colors. They were called comparison bottles.

COMPARISON OF COLORS PRODUCED, USING AN ALKALINE MOLYBDATE SOLUTION ON THE ONE HAND AND A SOLUTION OF YELLOW PRECIPITATE ON THE OTHER.

Standard molybdic acid solution: 1 cc.=0.004108 gram MoO_3, equivalent to 0.000073 gram phosphorus.

Standard phosphomolybdate solution: 1 cc.=0.00000613083 gram of phosphorus, 5 cc.—0.419 cc. standard molybdic acid solution. Yellow precipitate was dissolved in about the theoretical amount of sodium hydroxide.

COMPARISONS.

Place the standard solution in the bottle, filled half full with water, and passed hydrogen sulphide until solution is saturated. Then filled the bottle to the neck and compared the resulting colors.

Phosphomolybdate solution.	Molybdic acid solution.	Color
1	5 cc	Dark Amber
2	0.419 cc	Light "
3	10 cc	Dark "
4	0.838 cc	Light "

It was carried out a number of times, using different amounts of phosphomolybdate solution, and comparing with an equivalent of molybdic acid solution, always getting a darker color from the phosphomolybdate solution.

This result shows that a standard solution would have to be made by dissolving phosphomolybdate precipitate in sodium hydroxide.

EFFECT OF AIR ON THE FINAL COLOR.

Placed 5 cc. of the phosphomolybdate solution into two bottles, filled half full with water and passed hydrogen sulphide till saturated. Then filled to the neck with water.

Bottle No. 1 was tightly corked. Bottle No. 2 was poured into a 12 cm. porcelain dish and exposed to the air. At the end of two weeks the solutions were darker than when at first prepared, but exactly matched.

From this it was shown that air had no effect on the color. Here the essential fact was noted, that equal quantities of phosphomolybdate dissolved in sodium hydroxide gave the same intensity of color.

EFFECT OF QUANTITY OF SODIUM HYDROXIDE.

By numerous experiments, placing 1cc, of standard phosphomolybdate solution, in comparison bottles and then treating them with hydrogen sulphide for five minutes, preparing other bottles in like manner, but adding known amounts of Na OH in excess, it was found that Na OH four times in excess of the amount necessary to dissolve the yellow precipitate was not detrimental to the resulting color. This fact allows the operator a certain latitude in dissolving the yellow precipitate.

EFFECT OF DEGREE OF SATURATION BY H_2S.

Phosphomolybdate solution.	H. S. allowed to pass at the rate of 6 bubbles per second.	Color.
1. . . . . 1 cc	10 seconds	Straw.
2. . . . . "	15 "	Little Darker
3. . . . . "	20 "	Light Amber
4. . . . . "	25 "	Little Darker
5. . . . . "	30 "	Darker.
6. . . . . "	35 "	Darker.

The passage of hydrogen sulphide was continued for five minutes when the yellowish red color appeared permanent. Further treatment with hydrogen sulphide is necessary.

This condition can be and was obtained in the analysis made by passing hydrogen sulphide into the solution for five minutes, at a moderate rate. With sufficient alkali the fluid turns black.

It was found that one combined weight of sodium hydroxide in excess of that needed to dissolve the yellow precipitate always gave the right result. That is, $\frac{1}{2}$ of the amount of sodium hydroxide necessary to dissolve the yellow precipitate, in excess.

SOLUTION OF YELLOW PRECIPITATE.

Various methods are tried.

1. The addition of N/2 sodium hydroxide was made drop by drop, directly to the phosphomolybdate precipitate. This dissolved the precipitate, but it proved necessary to add sodium hydroxide in great excess.

2. A hole was made in the filter with a platinum needle, and all the precipitate washed into a 100 cc. measuring flask, then added $\frac{N}{2}$ Na OH till a clear solution was produced. This method gave better results, but shreds of the filter appeared in the solution.

3. The method followed was: to churn the yellow precipitate with very hot water, then to add $\frac{N}{10}$ Na OH till a clear solution is obtained in the filter, and to let this clear solution run through. Repeat until all the precipitate is dissolved. This method took just about the theoretical amount of sodium hydroxide to dissolve a given quantity of precipitate. It is advisable

not to add sodium hydroxide to the precipitate before churning with hot water, as the filter is in danger of charring. The presence of nitric acid with which the yellow precipitate is washed, does not interfere with the reaction and it need not be removed before adding the sodium hydroxide.

DELICACY OF COLOR REACTION.

For the following tests Nessler tubes are used. These were 16 M.M. bore: 30 cm. long and the 50 cc. of solution has a depth of 24.5 cm.

The standard phosphomolybdate solution contained 0.0000089 plus gram of phosphorus in 1 cc. The yellow precipitate was dissolved in 1½ times the amount of sodium hydroxide theoretically necessary. By numerous tests it was found that it was easy to determine a difference of 1/10 of a cc. or 0.00000089 plus gram of phosphorus.

THE FOLLOWING METHOD OF PROCEDURE IS RECOMMENDED.

Weigh off 2 grams of pig iron or steel into a 12 cm. porcelain dish. Cover with a clock glass and add 40 cc. of nitric acid (1.20 Sp. G.) After the first violent action is over, place over an Argand flame and heat, to dryness. When dry remove the clock glass and bake until all the fumes are driven off. Let cool, then add 30 cc. strong hydrochloric acid. Cover with glass and place on Argand burner; heat rapidly until the first appearance of insoluble ferric chloride on the bottom of the dish. Add 10 cc. strong nitric acid, and when violent action has ceased, cool by adding 50 cc. of water. Filter and wash with two per cent. nitric acid, then add strong ammonia to the filtrate until a permanent precipitate is obtained. Add strong nitric acid in slight excess. The solution should now have a clear amber color. Heat or cool to 85°C and quickly add 50 cc. of ammonium molybdate solution.* Shake strongly for five minutes, and then let the precipitate subside. Filter through a 9 cm. filter and wash with

*The ammonium molybdate solution used was prepared as follows: Dissolve 225 grams of molybdic acid in a mixture of 600 cc. water and 400 cc. strong ammonia. Add this solution to 2½ liters nitric acid (1.20 Sp. G.). Keep in a warm place over night. Filter, and it is ready for use

two per cent. nitric acid. Place the funnel with the precipitate into the neck of a 100 cc measuring flask.

Churn the precipitate with hot water and add $\frac{N}{10}$ Na OH until all the precipitate is dissolved. Read the burrette containing the $\frac{N}{10}$ Na OH and add one-half of the amount of Na OH necessary to dissolve, in excess. Fill the flask to the mark. Pour the phosphomolybdate solution into a burrette, and take an aliquot part and place in a 50 cc. Nessler tube. Fill half full with water and pass hydrogen sulphide at a moderate rate for 5 minutes. Place the tube into boiling water and let stand for 5 minutes. Remove and fill to the 50 cc. mark. Compare with the standard. Place 10 cc. of standard solution into a Nessler tube. Fill half full with water and pass hydrogen sulphide for 5 minutes. Place in boiling water for 5 minutes. Remove and fill to the 50 cc. mark.

Compare the colors of the standard and unknown solution. by looking down through the tubes, having a bright surface under the tubes to reflect the light upwards.

STANDARD PHOSPHOMOLYBDATE SOLUTION.

The yellow precipitate was obtained in bulk, by precipitating sodium phosphate with ammonium molybdate and thoroughly washing the precipitate, with two per cent. nitric acid and drying in a System oven. Take 0.2737 gram of yellow precipitate. Place into a 500 cc. measuring flask and add $\frac{N}{10}$ Na OH just to dissolve. Then add $\frac{1}{2}$ of the amount necessary to dissolve in excess, and make up to 500 cc. 10 cc. 0.000009122 plus gram of phosphorus.

If the standard phosphomolybdate solution is stronger than here given, 10 cc. will give a color too dark for comparison.

$\frac{N}{10}$ Na OH is made by dissolving 4 grams pure Na OH and making up to 1,000 cc. Its strength need not be determined further.

The following are phosphorus results, obtained in pig iron and steel, which Mr. Camp, of Carnegie Steel Co., and Mr. Glass, of La Belle Steel Works, kindly furnished me.

*Method of Iron Analysis by Francis C. Phillips, Page 43.

Low phosphorus metal.	Phosphorus by titiration with standard Na OH 0.044%.	Phosphorus by above method.
1 . . . . . "	. . . . . "	. . . . . 0.0436%
2 . . . . . "	. . . . . "	. . . . . 0.044 %
3 . . . . . "	. . . . . "	. . . . . 0.0439%
4 . . . . . "	. . . . . "	. . . . . 0.0441%
5 . . . . . "	. . . . . "	. . . . . 0.0436%

Basic steel.	Phosphorus by above method.
1	. . . 0.02211%
2	. . . . . 0.02184%

Mr. Glass has no phosphorus results on this metal, as it was a manganese standard.

He thought it would run from 0.015% to 0.03%, and said a result of 0.022% would be considered satisfactory at the works.

Bessemer pig iron.	Phosphorus by alkakinetric method.	Phosphorus by colorimetric method.
1	0.081%	. . . . . 0.084 %
2	"	. . . . . 0.086 %
3	"	. . . . . 0.0835%
Bessemer Pig Iron	0.102%	
1	"	. . . . . 0.087 %
2	"	. . . . . 0.089 %
3	"	. . . . . 0.087 %
4	"	. . . . . 0.088 %
5	"	. . . . . 0.0865%
Low phosphorus metal	0.042%	
1		. . . . . 0.0419%
2	"	. . . . . 0.0419%
Bessemer Pig Iron	0.088%	
1	"	. . . . . 0.079 %
2	"	. . . . . 0.081 %
3	"	. . . . . 0.083 %
4	"	. . . . . 0.0805%

The phosphorus given above under alkalimetry is an average of from 2 to 5 results, done by the men at the works.

Standard phosphorus in pig iron. Mr. Camp.	Phosphorus by weighing yellow precipitate.	Phosphorus by colorimetric method.
1	0.109%	0.10834%
2	"	0.10875%
3	"	0.1093 %
4	"	0.1095 %

STRUCTURAL SECTION.

A meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held at the Society's room, 410 Penn Ave., Pittsburg, Tuesday, October 25, 1904.

The Section was called to order by the chairman, Mr. Frans Engstrom, at 8:25 P. M.; thirteen members and vistors being present.

Subject selected for discussion at the November meeting: Reinforced Concrete.

The chairman appointed the following committee to nominate officers for the Section for 1905, to report at the November meeting: Emil Swensson, J. K. Lyons, B. V. Somerville, C. A. Lindstrom, H. C. Gould.

The paper of the evening, "Structural Features of the Phipps Power Building," was read by Mr. Edward Godfrey. This was followed by a general discussion.

A vote of thanks was tendered the author of the paper.

On motion Section adjourned at 9:20 P. M.

WILLIS WHITED,
Secretary Structural Section.

STRUCTURAL FEATURES IN THE PHIPPS POWER BUILDING, PITTSBURG, PA.*

BY EDWARD GODFREY.

The design of the structural steel works of the Phipps Power Building did not present many unusual problems. It was largely a matter of providing beams and girders to carry certain well-defined loads, and columns to support loads equally determinate.

The live load for which the floors were proportioned is 250 pounds per sq. ft. The live load on the roof was taken at 50 pounds per sq. ft. The columns were designed to carry all of this live load, with no reduction for lower stories, as might rationally be allowed.

The I-beams in the floors were proportioned for 1,600 pounds per sq. in. extreme fibre stress, and the girders for 14,000 pounds per sq. in., flange stress on the net area of flanges; no part of the web plate being counted in as flange.

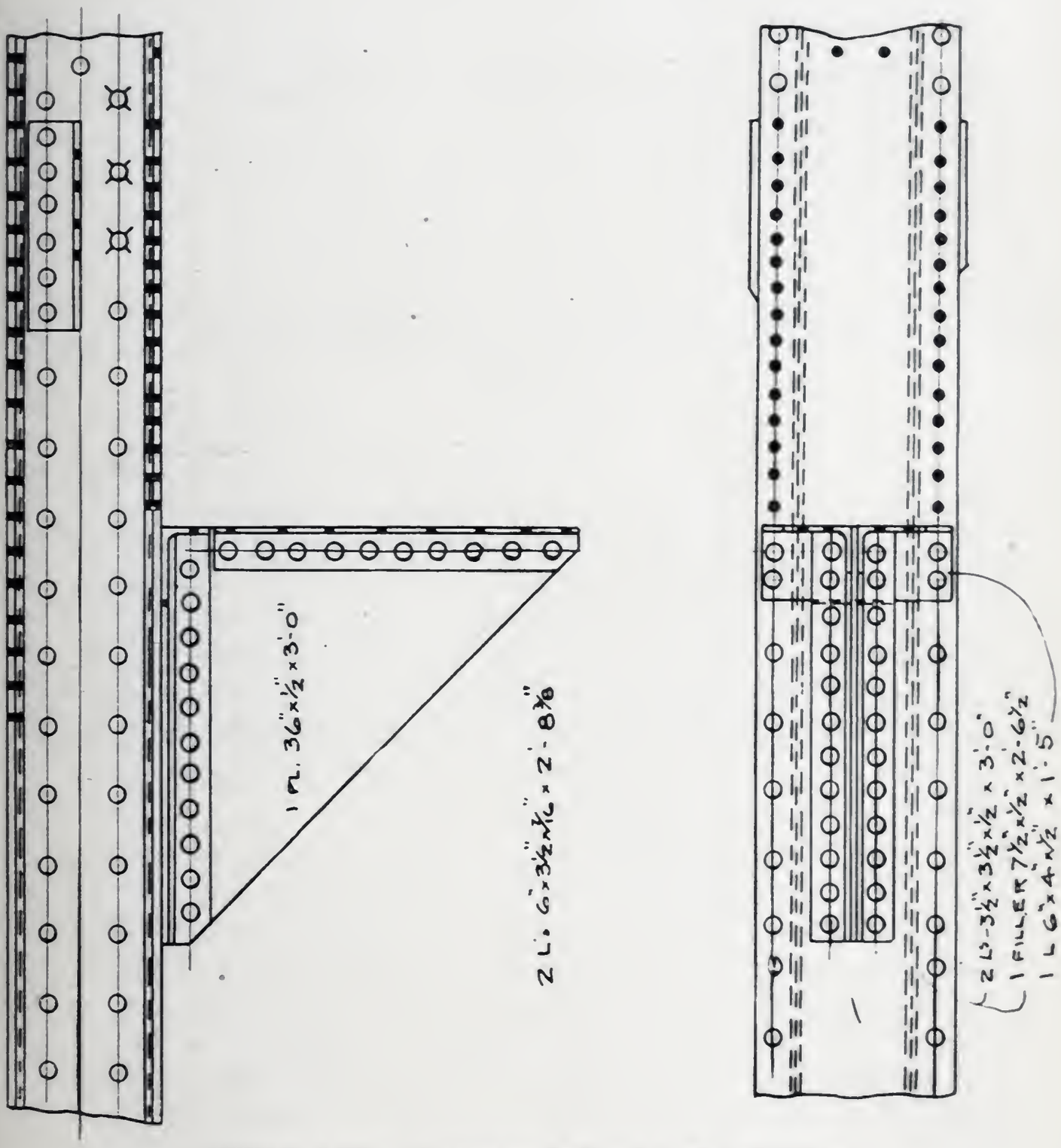
The unit load allowed on columns is that prescribed by the New York Building Code, or $15{,}200 - \frac{58\ l}{r}$

In plan, the building is 100 feet square out to out of walls. It is ten stories in height, the first three stories being 24 feet, and the remaining stories 13 feet from floor to floor. There are only two rows of interior columns in the direction normal to Cecil Alley, thus making the span of girders 32 ft. 8 in. In the other direction the spacing between columns, except in the front and rear bays, is 13 feet. The large floor space carried by the main girders and the interior columns required that these parts be unusually heavy.

The girders for the regular floors are of the built plate girder type, having single webs. On the second and third floors, where boilers with their heavy walls are carried by the steel work, the main girders are of the box girder type, having two webs.

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*Paper read before the Structural Section at the October meeting.



Interior Girder Connection, Phipps Power Building.

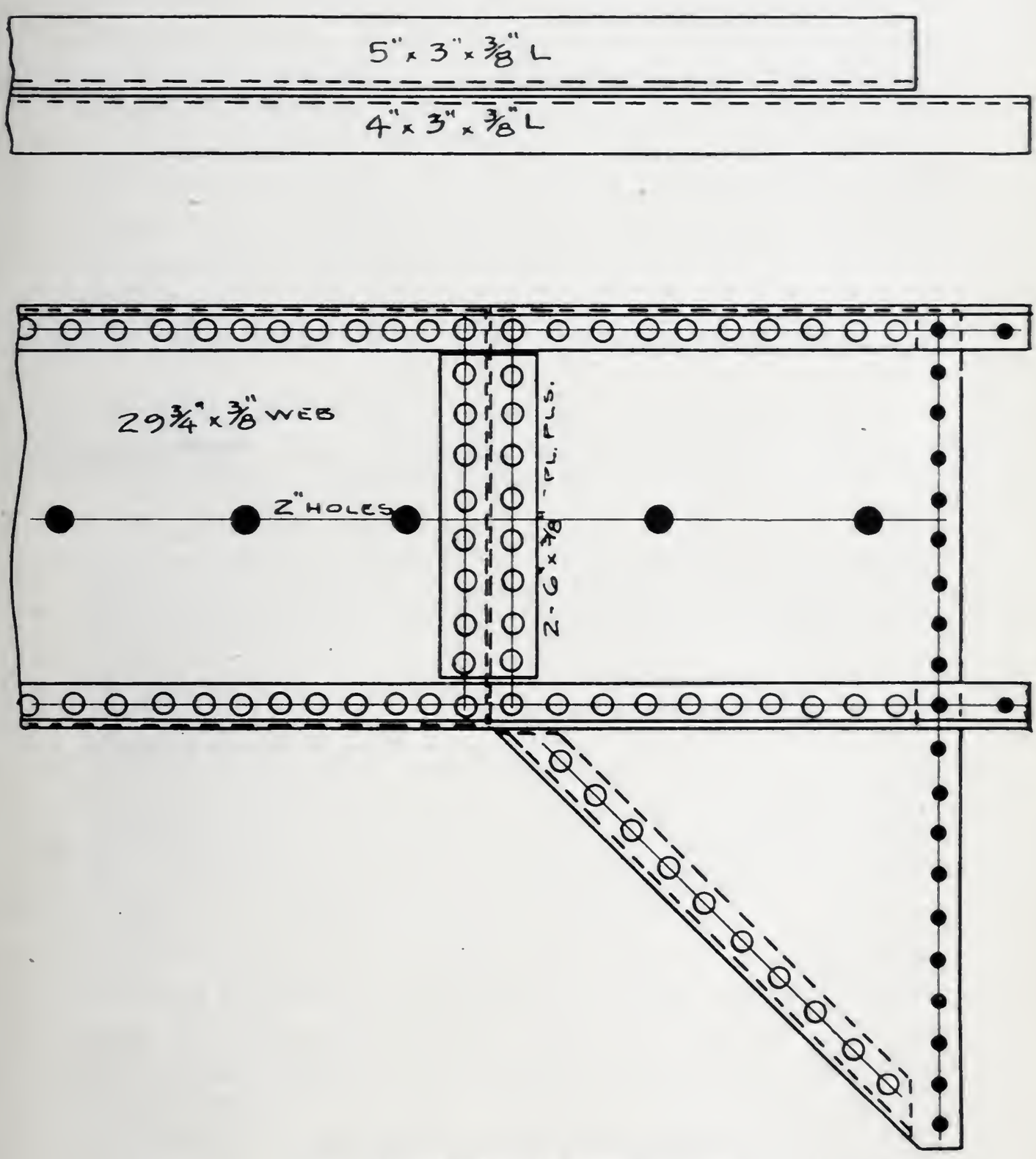
The columns had to be made of a style that would admit of increasing the sectional area very greatly on account of the heavy loading. The style best suited to this requirement was thought to be a column composed of two channels and two plates for the upper sections, increasing the size of channels and plates toward the lower stories, adding plates on the back of these channels as still greater area was required, and finally adding two channels back to back with plates riveted to web at the center of the column for the very heavy sections. The maximum sectional area used was 14,344 sq. in. This is made up of

4—15″ channels, 55 pounds.
2—20″ x 1″ plates.
2—14 3/4″ x 11/16″ plates.
2—14 3/4″ x 5/8″ plates.

Where the section of a column changed from one having two channels to one having four channels, the pressure is communicated into the added middle channels by means of two short channels similarly placed at the bottom of the column having but two channels. These are about two feet long. The columns are spliced by two side plates and have distributing plates in horizontal position which vary from 3/4 in. to 1 in. in thickness.

The columns rest upon cast iron bases 2 ft. 6 in. and 3 ft. high. These were set in place and grouted with cement grout, and the steel columns were bolted to them.

The bracing of the building is effected by means of gussets. The floor girders have brackets under them where they connect to the columns, and these brackets have substantial gusset plates connected to the bottom flange of the girder by means of angles. The ends of girders have plates the width of the column, shop riveted to the end connection angles, and field riveted to the columns. Floor beams connecting to columns have gusset plates on the brackets on which they rest and are riveted to the same by means of angles. A lug angle provides a top flange connection between these beams and the column. At each floor, as well as at intermediate levels in the 24-ft. stories, there is a line of wall girders completely surrounding the building. These girders are 30 in. deep and have stiffened gusset plates reaching 30 in. down



Wall Girder, Phipps Power Building.

the column. Thus five feet of the column is held by the wall girders, offering very effectual wind bracing.

The wall girders support the walls at these various levels and carry its weight to the columns. They are not in the middle plane of brick walls as the columns and the wall in the story below offer sufficient steadiness to the walls to prevent eccentricity of loading on the girders. The connection to the column is by means of a line of rivets five feet long, the girders are on the outside line of columns, thus serving to balance, to some extent, the weight of floor girders. The wall girders have holes punched through the webs at intervals for the insertion of ties to hold the parts of the wall together which are separated by the web of girder.

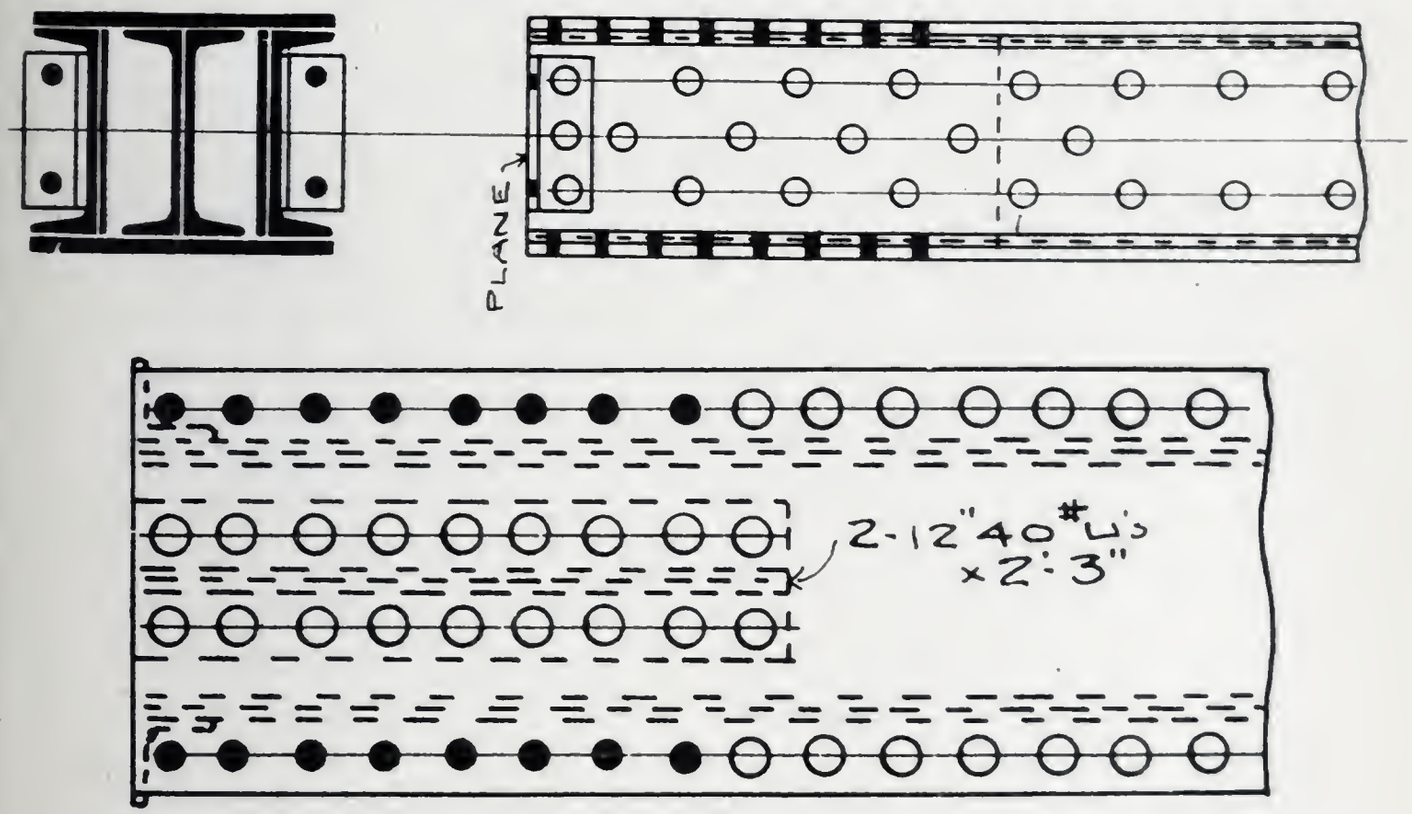
The combined gusset and bracket support under the beams and girders is not of the usual form with angles mitred at the corner, but has a horizontal shelf angle under which is a pair of close fitting stiffener angles. Between these angles the gusset plate is riveted. Thus the load of the girder or beam is not borne by the gusset out from the column as a cantilever, but rests upon a bracket close against the column, leaving the gusset plate to act in its proper function as a brace. Under the box girders there are double gusset plates.

The connection of beams to girders is by means of an angle shelf having a stiffener angle underneath. The top level of beam is one inch below that of girder and the top flange of beam is riveted to top flange of girder.

In the middle of the building opposite the fourth and fifth stories there is a coal bin with a capacity of about 2 1/4 million pounds of coal. This bin is box-shaped with the corners beveled off at 45 degrees, cutting off seven feet from bottom and side. The load of the bin is carried by double girders three feet deep. The length of these girders is about four feet less than the distance center to center of columns, and in order to relieve the columns of all bending from eccentric loading, vertical girders are riveted to the side, extending up to the sixth floor line, or for the full depth of the bin. Thus the sixth floor girders resist the thrust of these vertical girders where they tend to come together above the top of bin. In addition to this, the corner brackets,

as well as arched brackets under the girders, make this part of the construction exceptionally rigid. The bottom of the bin is lined with 5/8″ plates; the sloping part of the sides, with 1/2″ plates; the vertical part of sides, with 3/8″ plates. Beams are spaced 3 to 3 1/2 feet.

For the lateral pressure on the sides of the bin the action of coal was taken as analogous to that of a fluid, but the weight per cubic foot was taken as one-third that of the weight of coal. This is equivalent to the method which considers a wedge of granular substance sliding without friction on a slope bisecting the com-



Column Splice, Phipps Power Building.

plement of the angle of repose, but is more simple in its application.

The total weight of the cast column bases, 38 in number, is 305,510 pounds.

The weight of columns is 1,829,367 pounds.

The total weight of structural material, including castings, in the entire building is 5,742,463 pounds.

This is about 3 1/2 pounds per cubic foot of the volume of the building, or 574 pounds per square foot of the ground plan.

There were about 80,000 field rivets to drive.

As a comparison with other local buildings the following are about the weights per cubic foot of a number of Pittsburg buildings:

Arrott Building, 2.8 pounds of steel per cubic foot.

Farmers Bank Building, 2.3 pounds of steel per cubic foot.

Empire Building, 2.1 pounds of steel per cubic foot.

Oliver Building, 1.8 pounds of steel per cubic foot.

OCCURRENCE OF OUR BUILDING STONES.

BY F. Z. SCHELLENBERG.

From 1,500 feet thickness of outcropping sedimentary rock-measures spread around in Allegheny and adjoining counties, the city of Pittsburg, at the center, derives its supply of native stone. The stratigraphic section range is through the whole of the carboniferous.

The topography favoring the access to the rocks is predicated on their ancient side compression from the southeast making the corrugation with northeast trend of the anticlinals and synclinals; the general rise toward the northeast of these axes of the folds though in broken line and profile; and then the erosion, which is still going on generally toward the northwest; the waters cross cutting gaps on northwest courses in alternation at right angles with flat valleys followed on the strike.

With the variety of exposures in the combined effect is the change in elevations of surface throughout our territory from 2,400 feet above sea level to only 650 feet above.

Building stones continue to be quarried here in the city and nearby for lighter masonry, as house basement walls, from the layers called the Morgantown sandstone, situated about 150 feet under our Pittsburg coal seam. Formerly used more generally they proved less resistant to the weather, but it is noteworthy that the new edifice for the First Presbyterian Church on Sixth Avenue is being built of Morgantown sandstone brought by boat from Geneva, on the Monongahela river. Indiana limestone is to be used in the trimming.

About 400 feet lower geologically occurs the Mahoning sandstone, a better freestone immediately on top of the Freeport coal seam. It has been used as ashlar for many heavy structures, but as it is only accessible near here on the Allegheny and Ohio at its increased top thickness of varying

strata, it is not chosen as much for bridge masonry as the more generally massive Beaver river valley stone, which comes 600 feet lower in the column from No. 12 formation of this Paleozoic epoch.

No. 12 sandstone stands out accessible too in the mountain gaps next east of us, and under it there, with No. 11 Mauch Chunk red shale between, comes No. 10, the sileceous limestone called Ligonier block in this market.

The Bedford-Indiana limestone imported here from the west is probably contemporary in deposition with this No. 10 of our Appalachian field.

Berea grit is lower down; it is brought out of northeastern Ohio in immense quantities and is called Cleveland stone here.

We get brown stones from the Upper Lakes region that are older, Devonian or Silurian, but the brown stones from the east are Mesozoic, of later formation than our native stones.

We regard the New England granites we use as of old origin.

Immediately over the Pittsburg coal seam is the Pittsburg sandstone in thin-bedded rough layers, but from some points natural surface flagstones used to be obtained from that horizon.

Four hundred feet above is the Waynesburg sandstone on the Waynesburg coal seam; it is massive and has been used inland and on the Monongahela river in cut stone work. There is but one ledge of it in Allegheny county—Rocky ridge in Bethel township.

It is iron that has had most to do with the color of these stones. They are named gray, buff, or brown as the luminous blue, the protoxide imparts to clear silex or calcite, departs through ochre to rustiness given by the hydrated sesquioxide, which is then changed by heat to red from the iron's loss of the combined water, as naturally in hematite or artificially in common brick.

Our stone color in flat tint on a drawing may be a neutral tint of India ink thinned, or may be a brilliant gray from a mixture of crimson lake with Prussian blue.

The brown sandstones we get are of the New Red formation, whether from Hummelstown or the Connecticut River valley, but we say are Old Red if from the northwest: and it is said there are Old Red sandstone house trimmings to be seen that were imported from Scotland, on sentimental grounds, we may suppose.

The Ligonier stone occurs bluish gray generally, but from the Laurel Hill there is a chocolate-brown variety tinged evidently from the red shale formation atop. Ligonier stone does not split, but spalls alike in all directions. The ledge 50 feet thick is interrupted by frequent cleavage. Several handsome buildings have been erected faced with the stone in large size, and very durable flags making sidewalks in East Liberty were sawed from it. But its widespread vogue is the block stone paving of the city. It is, too, the favorite macadam road metal in Allegheny county. The paving blocks, handmade, hammer-spalled, are now better made and laid here than formerly. When too long, wide and rough sided the joints gape wide and the surface wears cobbly.. Belgian block specification would call for 3½-inch width to suit the horse's hoof, 7 inches depth and about 8 inch straight enough length to have half-inch joints.

Cleveland stone is from a formation 10 to 75 feet thick, it is generally silex sand compacted by pressure—hardly otherwise bound—and much of it may be called tender grit as the grains let go easily.

In the great use of it in these towns, as in five-foot wide sawed sidewalk flags, there are specimens especially inferior in appearance because of blotches of petroleum from cavities opened in the surfacing.

Selected, it comes in pleasing solid color ready for house lintels and sills or entire house front facing courses, or in large blocks that are easy to split by plug and feather and work into sizes and shapes by hand tooling. The Carnegie Institute is built of this stone and shows much cut work intended for ornamentation.

The Indiana limestone is in texture a fine sandstone that lends itself even to carving. The Gothic trimmings of this

stone in the Third Presbyterian Church is beautiful, and there is the contrast with the peculiar russet Beaver stone in the body of the walls. But the new Cathedral, altogether of this limestone, promises to be a magnificent Gothic temple. The Wabash railroad depot is almost too elaborate in large members of this stone. The County Court House, whose architecture has been much admired, is of granite, but its interior arching is of the Indiana limestone, and of this it has been noted that its carving there does not do the capability of the stone justice, being kept in low relief as this had to be so in the granite parts. In passing it may be remarked that the exterior granite capitals at the window openings are most varied in pattern in this Court House, and interior capitals are so also, even the small balustrades repeat only in sets of five.

Our member, Thomas H. Johnson, made a report of experiments upon the transverse strength and elasticity of building stones which was published in the 11th report of the State Geologist of Indiana in 1882. The report is full as to the qualities of the Indiana limestone there termed Oolitic from its fish-egg-packet, roe-like appearance at the south of the extensive territory in which it is found.

It is 96 per cent. carbonate of lime, occurs 40 feet in thickness, and is homogenous so as to be alike strong on edge or on bed. The mighty stones of Baalbek could readily be surpassed in these quarries. To this may be added that the Baalbek walls have stones 20 feet square by 60 feet long, and none as great in section has been heard of in ancient or modern times; but there were shafts and slabs quarried of much greater length, and such have been at least broken out of the solid intact in American granite quarries. The remarkable evenness of bedding in the Berea grit has allowed extraction of stone blocks 10 feet square and only $1\frac{1}{2}$ inches thick, and in one case a strip 150 feet long, 5 feet wide, and but 3 inches thick was reported as raised intact from the quarry bed.

BRICK MASONRY.

BY L. C. WELDIN.

Bricks are very convenient building materials. They have been used from the earliest times, and we doubt not will continue to be used until the end.

The materials from which bricks may be made form the greater part of the surface of the inhabited earth and are so distributed as to almost eliminate the item of freight charges.

Beginning with the hand-made and sun-dried adobe, bricks came to be made by millions, of the finest clays, burned hard in patent perpetual kilns, and now we have the lime and slag sand bricks, dried in a few hours by steam, and guaranteed to bear the highest tests. Of all colors, sizes, and shapes, bricks are a building material of the greatest importance. The small size of those in common use, and the consequent great number of joints, has been objected to by the architects, but this is largely overcome by coloring the mortar. Recent great fires have shown that brick are the best material to resist this destructive agent. Brick, as now made, vary considerably in size. This has, no doubt, for its original cause the great difference in shrinkage of clays in burning. The usual $4 \times 2\frac{1}{4}'' \times 8\frac{1}{4}''$ size was no doubt adopted because of convenience in handling. All formulæ for calculating the number of bricks must be approximate. We may, however, estimate that six hundred bricks to the cubic yard of masonry will contain a liberal allowance for waste. A wall nine inches thick requires fifteen bricks, and a wall thirteen inches thick requires twenty-two and a half bricks to the square foot of surface; a seventeen-inch wall, twenty-nine bricks; a twenty-two-inch wall, thirty-four and a twenty-seven-inch wall, forty-four bricks to the square foot of space. These figures are based upon usual practice as to joints and waste; openings of less than one hundred square feet are counted as solid.

Colors.—The presence of iron in the clay gives color to the bricks. A larger proportion of iron gives bright red, and smaller quantity lighter tints, shading off to orange. A trace of lime gives the cream colors. The pure clays burn white. For good effects the shades are selected so that one side or front of a building shall all be as nearly of one shade as may be.

Strength.—The resistance to crushing depends upon the material used and mode of manufacture; the softer ones bearing four hundred to six hundred pounds per square inch, while good hard bricks may bear a pressure of two thousand to five thousand pounds per square inch. The sand-lime bricks now being made are guaranteed to bear three thousand pounds per square inch. Brick masonry may bear as much as fifty tons per square foot, but should not be loaded to more than five or six tons per square foot. Where it is necessary to do so, good hard bricks laid in cement may be loaded to ten or twelve tons per square foot without danger.

Absorption of water.—Hard bricks should not absorb more than 10 per cent. of their weigth. A less amount would be preferred, although some bricks absorb as much as 20 to 30 per cent.

Weight.—Bricks weigh from from one hundred and fifty to one hundred and sixty pounds per cubic foot. Brick masonry weighs from one hundred and twenty to one hundred and thirty pounds per square foot.

Because of their shape and size, bricks are very well adapted for use where masonry is carried up in narrow piers, or must contain many pockets or openings, as in foundations for machinery. They are much used for engine foundations. Ornate shapes are used by architects to carry out their designs in cornices, pilasters, belt courses, etc.

Bonding.—In ordinary masonry it is customary to lay every fifth or sixth course as headers. The Flemish bond is made by alternate headers and stretchers in the same course. Metal bonds are much in use where entire fronts are laid as stretchers, and hollow walls are readily made by their use. There are many patterns on sale and most of them are very satisfactory, with the single exception that they may melt in

a hot fire and cause the destruction of a wall. Secret headers may be used by cutting off the corners and putting a whole brick in diagonally.

The rear courses should be level with the front ones to make good work.

Joints.—The joints should be straight and even and be neatly struck with the trowel. It is sometimes specified that two courses shall occupy five inches in height. In fine work the brick is squeezed down, making a thin joint. When the wall is to be pointed, the mortar must be raked out to give the pointing a good hold. Joints may be as much as a half inch thick if the mortar is good and worked stiff. A narrow border of mortar is sometimes put upon the front edge of the brick as it is laid. This is called buttering, and is done when colored mortor is used.

Thickness of Wall.—Most cities have passed ordinances specifying the thickness of walls allowed. For warehouse, Haswell gives from thirty to forty feet high, thirteen inches; from fifty to seventy feet high, seventeen and one-half inches; eighty feet, twenty-one inches; and from ninety to one hundred feet high, twenty-six inches thick. The engineer will probably prefer to calculate his thickness from the floor loads and then make the wall extra thick for safety. Bricks are well adapted to use in connection with the steel frame-work now in use, both for convenience in handling and great resistance to fire. They work well in connection with concrete, and because they are already prepared for use, are in many cases preferred to other materials.

Mortar.—For good work on dwellings we may specify fresh burned lime and clear sharp sand in the proportions of one to five, if the lime is good and the sand clean, or less sand if these conditions cannot be had.

Bricks laid in cement make good foundations. Cement in walls above ground is objected to by the bricklayer as it does not work as freely as lime mortar. Mortars adhere to bricks about as well as to building stone, but care must be taken that the brick is clear of dust and not too dry. Brick should be well wetted before using in dry weather, or they will absorb the moisture from the mortar and so destroy it.

To lay one thousand bricks requires sixteen or seventeen bushels of sand and about three bushels of lime. They will occupy about one and three-fourths cubic yards in the wall.

A Day's Work.—A man should lay one thousand bricks in seven hours, and requires one man to carry materials. For pressed brick fronts it will take them about fifteen hours to lay one thousand bricks.

We may then specify as follows:

All brick used to be good, hard, and well burned, no cracked or swelled brick allowed; to be laid in strong mortar of fresh burned lime and sharp, well screened sand; laid wet in dry weather, and kept dry in freezing weather; joints to be neat, straight, of uniform size throughout, and neatly struck on the face; all joints to be flushed solid, leaving no empty spaces; to be well tied with heading course every fifth course, and worked in regular bond; the bricks to build two courses to five inches in height; jambs and face of wall to be carried up plumb and true.

The inspector should see that the bricks are sound, straight and of uniform size, and have full sharp edges, and square and true sides. By striking two together he may soon learn to detect the hard ones by sound. The sand must not soil the hand, taste salty, nor contain small pieces of coal or other foreign matter. It must feel gritty to the touch. The lime must be pure, should be white and should all slake down to a fine powder.

MORTARS.

BY JOSEPH A. SHINN.

Mortar performs two principal functions: First, it forms a uniform bedding for the bricks or stones and enables the mason to equalize the slightly varying size of each; second, it adheres to the bricks and stones and binds them together.

The second function is universally recognized; the first receives little consideration, except by the operative mason.

The ancient Egyptians did not use mortar in their stone structures; the stones being dressed to absolutely accurate dimensions and practically polished on their bedding surfaces.

In ancient Babylon asphalt was used as a mortar. The first use of asphalt in modern times was by Eirinus, a Greek physician, in 1712, when it was used as a matrix for artificial stone, but without much success. Its successful application dates from the discovery of asphalt rock in France, in 1832, by Count Sassonay.

Mortar was made by the Greeks and Romans in much the same manner as at the present time. Where hydraulic lime was available its use was preferred. When fat lime was used in important structures, it was generally rendered hydraulic by the addition of ground burned clay "terras," or where Puzzuolani was available, by the use of that material in place of common sand.

In fat lime mortar the lime renders the mortar of easy working, because of its plasticity; the sand supplying stability to support the weight of the masonry before the mortar is set, and to prevent the shrinking of the lime which would destroy its cohesion.

Of more importance than either the quality of sand or lime is that the lime should be perfectly slacked. In Europe specifications require that lime should be slacked not less than

three months before being used. I have seen mortar used in this country in which the lime had not been slacked three hours.

Of nearly one hundred samples of lime mortar, taken from as many buildings, in New York City, in 1883, and tested by the writer, the average tensile strength per square inch, of stone mason's mortar, was 11 pounds, and of brick mason's mortar, 14 pounds, at 28 days.

Lime mortar does not indurate by the formation of silicate of lime, as is generally supposed, the hardening being due wholly to the carbonation of the lime.

During the past twenty-five years the substitution of concrete for stone and brick masonry has been so great as to suggest the possibility of its almost wholly replacing those materials in all kinds of structures. The stability of concrete structures is attested by the existence of large works built by the Romans more than one thousand years ago, with binding materials very much inferior to the Portland cement of to-day.

There is no material used in construction capable of as great abuse as is the mortar used as matrix for concrete.

With impure sand, poor cement and insufficient quantity, careless mixing and careless work in placing, concrete is redeemed only by the fact that most of the Portland cement now in use is of sufficient strength to overcome all these defects and still leave a margin of strength sufficient for the structure.

Where concrete is exposed to low temperatures, an insufficiency of cement to fill the voids in the sand is a matter of more importance in relation to the porosity of the concrete than to that of strength.

The proportions of sand in the face of concrete in this latitude should in no case be less than one of cement to three of sand.

DISCUSSION.

ROBT. A. CUMMINGS—There is some foundation work being constructed on the South Side by the Crauford Paving Co., for the Pittsburg Terminal Warehouse Co., which, I think, merits notice here. The ground consists of a miscellaneous lot of filling material, containing so much brick, stone, wood, etc., that it was not considered practicable to drive wooden piles, moreover, as the foundations were to carry large and costly buildings, something more durable was desired, so it was decided to drive concrete piles by the Simplex system.

The method is, briefly, as follows: A steel pipe about 16 in. in diameter and of sufficient length is provided with conoidal point 4 ft. to 5 ft. long of concrete, tenoned into its end. This pipe with the point inserted, is driven to the required depth with a pile-driver. The pipe is then filled with concrete and withdrawn as the filling proceeds, leaving the concrete point in place, and the hole rammed full of concrete. The piers carrying the building are built on clusters of these piles. Both ends of the pipe are re-enforced with heavy steel bands riveted on; and the splices in the pipes are made with faced butt joints and steel splice bands riveted on. The top end of a pipe, during driving, is fitted with a cast cap which fits between the leads of the pile-driver, so that it acts as a guide for the top of the pile and is fitted with a banded wooden block which receives the blow of the hammer. The hammer is heavy—about 2,800 pounds—and the fall is limited to about 15 ft. The piles are about 40 ft. long.

When the pile is driven concrete enough is dropped in to fill it to a depth of about 3 ft.; the pipe is withdrawn to near the top of the concrete and the concrete rammed. About 3 ft. more of concrete is dropped in, the pipe pulled and the concrete rammed as before. This operation is repeated till the pipe is entirely withdrawn and the hole filled. The power required to start the pipe up sometimes exceeds 25 tons, but after it is started there is little difficulty.

A few of the piles are pointed with cast-iron, but that is only in special cases. The cost of these piles is considerably

greater than that of wooden ones of similar length and diameter, but, of course, their durability in any kind of soil is unquestioned.

Another novel method of placing concrete is in use in Duluth harbor, where wooden piles are driven in deep water, sawed off, and a concrete wall built on them. In this case the concrete is deposited by means of the ordinary bottom-dumping buckets, but the buckets are covered with canvas to prevent the water from washing out the cement.

This work is done by the Government and they are using Universal Portland cement, made in Chicago. This cement is similar to that made in Elizabeth by the International Cement Co., i. e., it is made of blast furnace slag and lime ground together in the proportions to give the desired composition to the cement, clinkered and ground again, as is done with ordinary Portland cement.

GEO. T. BARNSLEY—I made a large number of tests of concrete and of stone in connection with the construction of the Wabash Bridge crossing the Monongahela river, at Pittsburg. They were made with the large testing machine at the Keystone Bridge Works and were mostly on 12 in. cubes.

I have not had time to tabulate any considerable number of the tests so as to prepare them for publication, but will give a few general results.

One test of sandstone, taken from what I consider the best ledge in the Beaver Valley gave a result of 10,133 pounds per sq. in. This result is exceptional. The concrete tests from two to two and a half years old, gave results ranging from 3,500 pounds to 4,200 pounds per sq. in. Gravel concrete. Allegheny River gravel.

Fig. 1 shows a specimen of concrete in the testing machine giving its first indication of failure. Fig. 2 shows a specimen at the moment of final failure. Fig. 3 shows a collection of specimens which have been tested to destruction, showing the approximately conical forms of the pieces, which indicate a homogeneous material.

E. K. MORSE—Large sized test pieces indicate better than small ones the real value of a stone for construction purposes, and if the test pieces could approach in size the stones used in

actual work, they would be still more valuable, but, if it is desired to compare the strength of different varieties of stone, it is important that the test pieces should be all of the same size. As the vast majority of tests of stones heretofore made, have been on 2-inch cubes, tests of larger sizes are of relatively little value for purposes of comparison. It is also a well-known fact that if the load is applied rapidly, the test will show greater strength.

Beaver sandstone, which is used very largely for heavy masonry in this vicinity, varies greatly in quality now, so much having been taken away from the better exposures. Mahoning sandstone from the northeastern district is a reliable material for heavy work. The pinkish colored variety is very fine. The name "peach blossom" was at one time suggested for it in the Kiskiminetas Valley. Mahoning sandstone hardens greatly on exposure and then the darkened rusty surface resists cutting tools almost like iron.

Our strongest stone is the Ligonier block, which at least, in the brown variety, has stood as high as 30,000 pounds per sq. in. compression.

Dressing test specimens weakens them more than superficially, therefore, they should always be sawed.

W. WHITED—About 17 years ago I made a test of a two-inch cube of slate from the New Rockland Slate Co. in Canada, which stood something over 37,000 pounds per sq. in., without failure. As that was the limit of the capacity of the testing machine, I cannot say what its ultimate strength might have been. The test was made on an Emery testing machine, at the Dominion Bridge Works, Lachine, Canada, and was made very slowly. I do not remember of having heard of any higher result being obtained with any kind of stone.

JOS. A. SHINN—In 1873 about 3,000 ft. of curbing was quarried from Beaver Valley sandstone and was not used until 1876. The contractor complained that it cost him more than twice as much to dress it as to dress freshly quarried stone.

In 1891 I examined a country quarry of sandstone in Holmes Co., Ohio, and expressed the opinion that it was too soft for

building purposes. I was shown a building that had been constructed of this stone several years before and found it had acquired a hardness equal to that of the best Berea stone. The crushing and transverse strength of stone should increase with increase in hardness.

DESCRIPTION OF WELL-KNOWN TYPES OF STEAM TURBINES WITH SPECIAL REFERENCE TO THE WESTINGHOUSE-PARSONS.*

BY R. N. EHRHART.

The trend of progress in steam engineering to-day seems to be along steam turbine lines. A glance at some of the recent contracts for large metropolitan power plants shows what an important factor the turbine is in modern steam engineering.

In considering the different types of turbines before the engineering public it is only necessary to examine four types; these four embrace all the fundamental principles of turbine construction, and we may say that all turbines are either combinations or modifications of them. The following are the four types to be considered: 1. De Laval; 2. Curtiss; 3. Rateau; 4. Parsons.

These may be divided into two groups: the De Laval and Curtiss being classed as nozzle turbines, and the Rateau and Parsons as impulse and combinations of impulse and reaction turbines respectively.

The diverging nozzle is one of the features of both the De Laval and Curtiss turbines. The nozzle may be defined as a device for converting the thermal energy of expanding steam into kinetic energy in the form of velocity energy of the expanding steam itself; that is, if a pound of steam expands between certain limits in a properly designed nozzle, it will issue with a velocity of such magnitude as would make its kinetic energy due to velocity equal to the heat energy given up during expansion, less, of course, a certain small loss due to molecular friction of the particles of steam upon themselves and upon the walls of the nozzle.

If a well-rounded orifice be subjected to the flow of steam between the ordinary limits of engine work, say 165 lbs. absolute initial to 2 lbs. absolute back pressure, it will be found that the

*Paper presented before the Mechanical Section of the Engineers' Society of Western Pennsylvania, Tuesday evening, October 11, 1904, at 410 Penn avenue, Pittsburg, Pa.

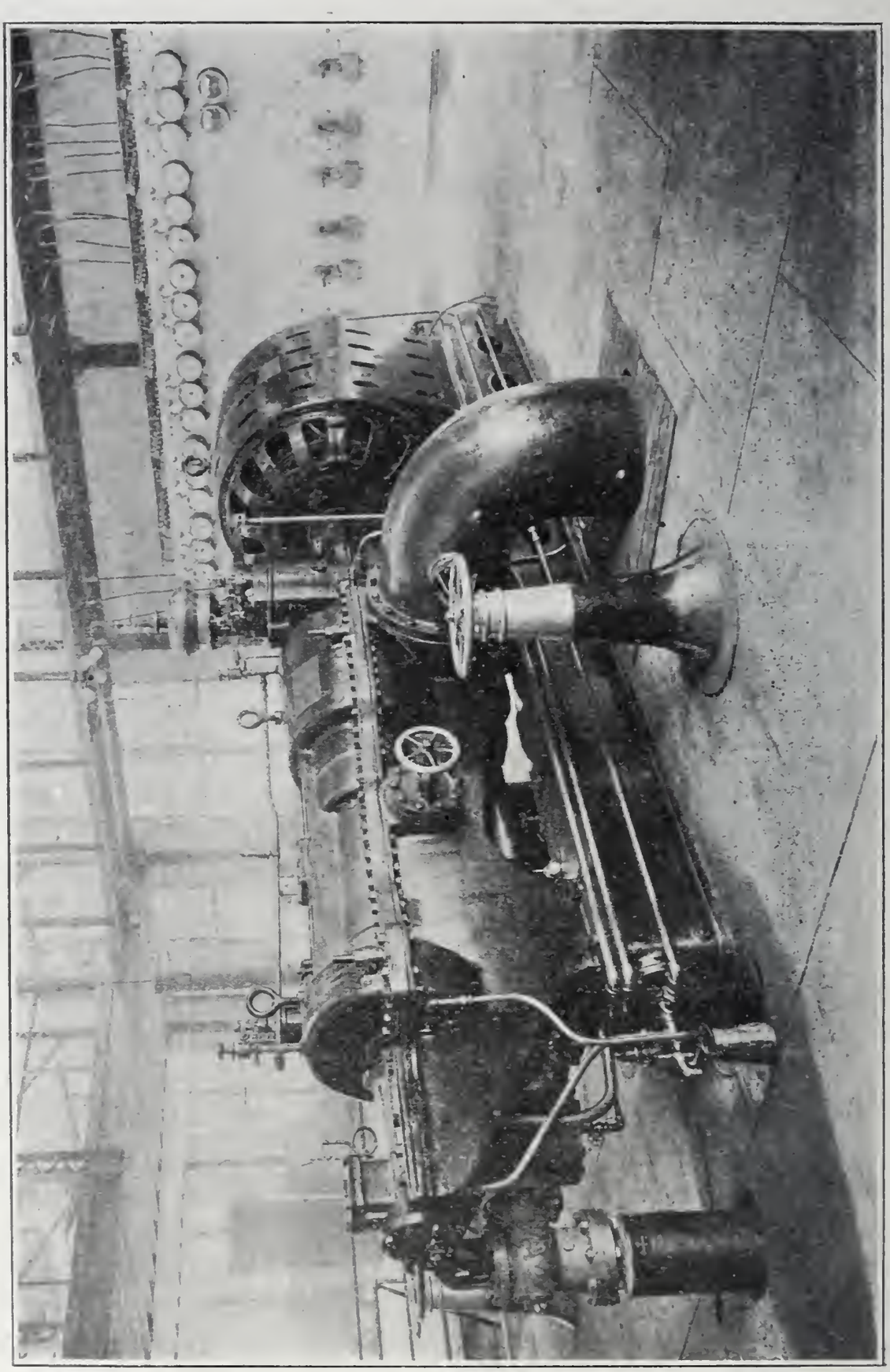


Fig. 1. 400 K. W. Westinghouse Turbine and Generator.

pressure of the jet at the point of exit from the orifice will be about 92 lbs. absolute per square inch. It will be noted that 92 is 56/100 of 165. If the back pressure is slowly raised the pressure of jet at orifice will not change until the back pressure just begins to exceed 92 lbs.

The conclusion is that a simply well-rounded orifice does not offer the facilities for expanding discharging steam to pressure below 56/100 of the initial pressure. If a diverging part be added to the outlet of the well-rounded orifice, and if it be given proper dimensions, it may be made to expand the steam to the desired back pressure within the nozzle itself, and the steam will issue with great velocity from the nozzle.

The steam during its escape has expanded from a high pressure to a lower one, and the work of the expansion has been done on no external object or substance, but has been utilized in accelerating the mass of steam itself, so that the steam issues with a velocity equal to the energy represented by the heat energy given up during expansion.

THE DE LAVAL TURBINE.

In the De Laval turbine the steam is fully expanded in a diverging nozzle, and the steam at high velocity is directed against a wheel with properly proportioned buckets on its periphery. The steam velocity is but partially utilized in the turbine, because the wheel would have to revolve at destructive velocities to entirely and most efficiently absorb the steam velocity under ordinary conditions. Under conditions of, say a 28-inch vacuum and 200 lbs. absolute initial pressure, we get velocities exceeding 4,000 feet per second, which is far higher than the muzzle velocity of modern high power artillery.

However, the form of turbine has been so perfected along mechanical lines that it is eminently successful as a form of steam motor for small sizes.

The standard form of this turbine is a turbine wheel revolving at speeds of from 40,000 R. P. M. in the smallest size to about 9,000 in the larger sizes. This is usually geared down by a 10 to 1 ratio gear, and in this way connected to the generator, pump or whatever is to be driven.

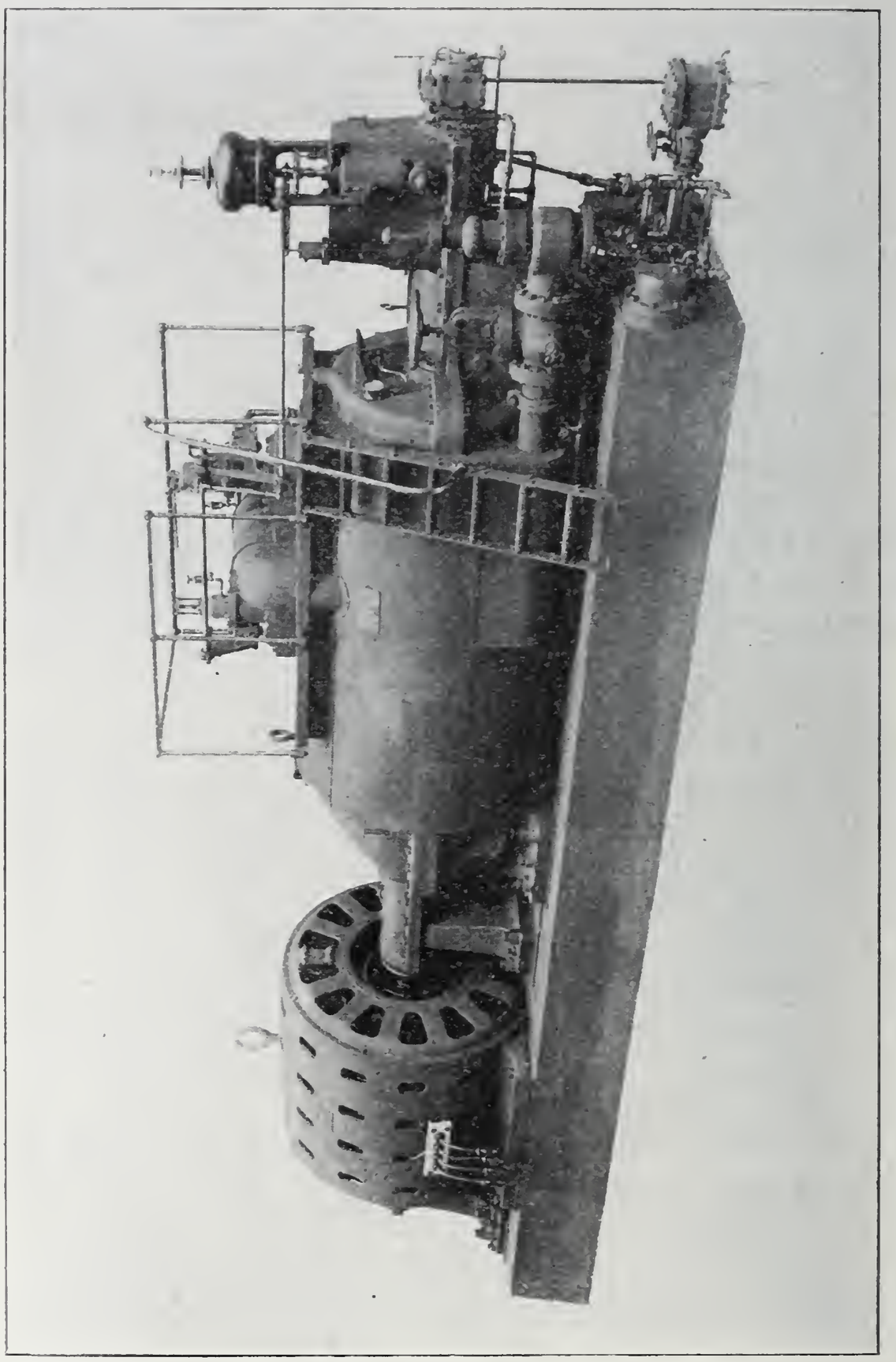


Fig. 2. 750 K. W. Westinghouse Turbine and Generator.

Governing is accomplished by an ordinary fly-ball governor which throttles the supply of steam.

The gearing for the turbine is a wonderful piece of work, but of necessity represents a loss of energy due to unavoidable friction. The De Laval turbine so far has been used to a great extent in small sizes, such as 20 to 50 Kilo-watts, and some machines as large as 200 K. W. are in operation. Above the latter figure other makes of turbine of direct connected type seem to be preferred by engineers.

THE CURTISS TURBINE.

This turbine utiliezs a nozzle or group of nozzles which discharges the steam at a relatively very high velocity against an annulus of moving buckets, the velocity is only partially absorbed, so that steam comes from the rotating row of blades with a very considerable velocity. A set of properly shaped stationary guide vanes then re-direct the steam with its residual velocity against a second annulus of rotating blades. There may then be enough alternative rows of guide vanes and moving buckets to entirely absorb the initial velocity of the steam. This may be carried out in stages to secure lower steam velocities; for instance, the first set of nozzles will expand the steam between the initial pressure and a lower limit, then have another set to expand from the latter limit to a still lower one. The number of rows of blades in each stage is dependent upon the peripheral speed of the turbine and the pressure limits expanded to.

This turbine as built at present has a vertical shaft supported by an oil step bearing. This is one of the radical points of the turbine, and the merits and demerits of this can only be proven by long and successful operation. This form of bearing necessitates the use of an auxiliary pump and a set of pressure accumulators for maintaining high, constant oil pressure at the step bearing.

The blades in turbines of the nozzle type are very likely to give trouble due to excessive erosion. This wear is minimized when superheated steam is used.

THE RATEAU TURBINE.

Consider a great number of De Laval turbines connected in series as regards steam flow, but all turning the same shaft. This

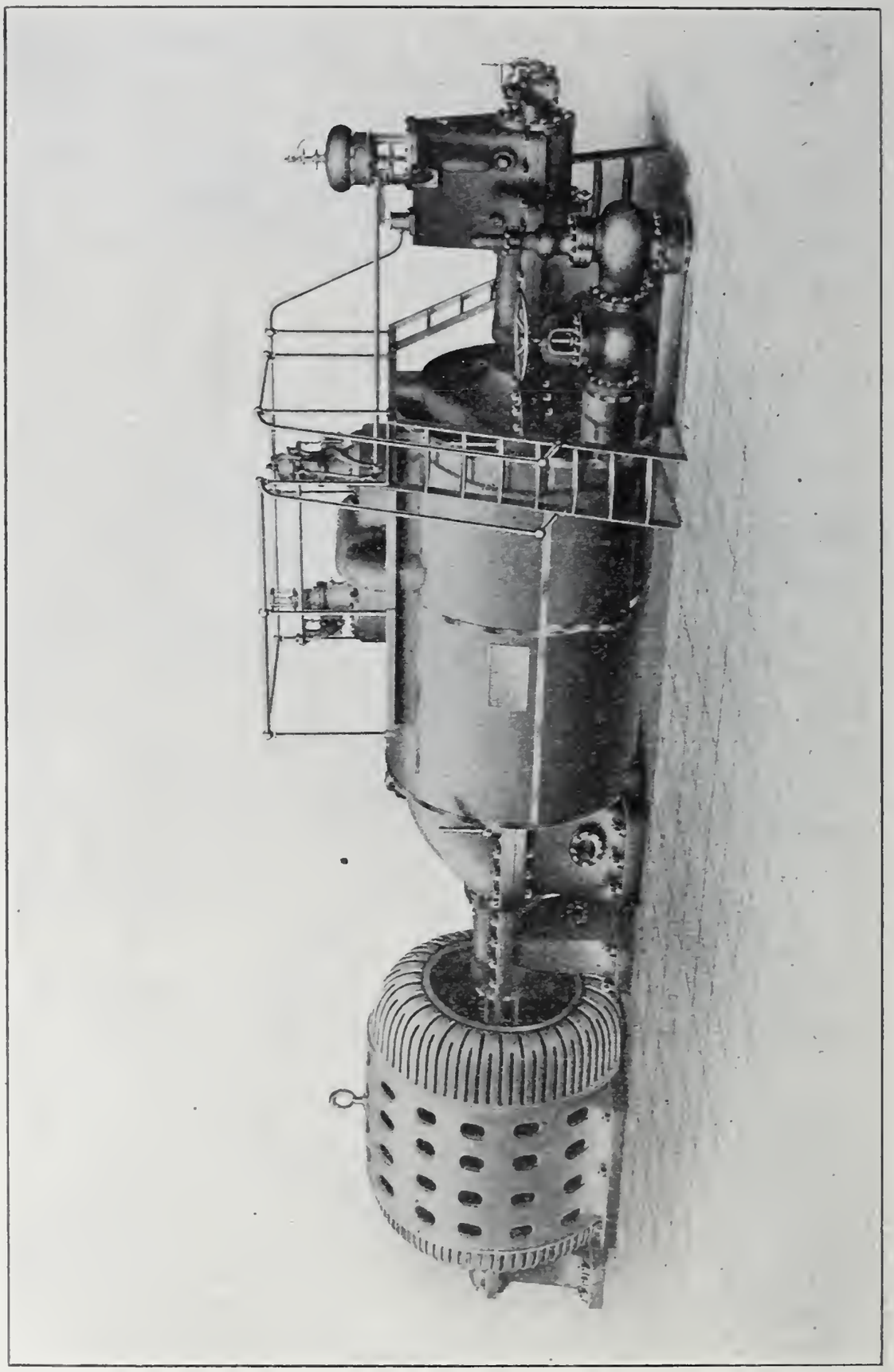


Fig. 3. 1500 K. W. Westinghouse Turbine and Generator.

may be taken to represent the Rateau turbine. Each turbine wheel revolves in a separate chamber, in the wall of which are guide passages which impinge steam from the preceding chamber upon the wheel; all expansion takes places in these guide passages which are really nozzles of the non-diverging order, no divergence being needed on account of the small difference of pressure between any two chambers of the series. By having a great number of wheels the pressure drop is small from one member to another of the series, so that the velocity of issuing steam at nozzle outlet is relatively low, requiring a low peripheral velocity of turbine wheel to effectually utilize said velocity. The remark may be made that in the Rateau turbine only part of the circumference of an individual revolving element is acted on by the steam. In the Parsons turbine the whole circumference is in action.

The steam velocities in this turbine are far lower than in either the De Laval or Curtiss. Prof. Rateau lays great stress on the necessity of keeping it low in the modern turbine, and even goes so far as to predict the dying out of the types of turbine using steam at high velocity.

In the Rateau and Parsons turbines 600 feet per second may be considered as the maximum steam velocity.

Inasmuch as friction varies as some exponent of the velocity greater than two, it is reasonable to assume that fluid frictional losses are high in turbines where steam velocity is high. The mere fact of excessive erosion proves this.

THE PARSONS TURBINE.

This turbine has probably met with greater success and wider adoption than any other form of steam turbine; it dates from the early "eighties," and since the original conception has changed but little in its general make-up. Nearly all work has been along the lines of improvement of details, making the engine perfectly trustworthy, economical and mechanical in every respect, so that today the Parsons turbine stands as an example of intelligent engineering along legitimate lines.

The Westinghouse Machine Company some years ago recognized the coming importance of the steam turbine as a prime mover, and began an extensive investigation of turbines. Many

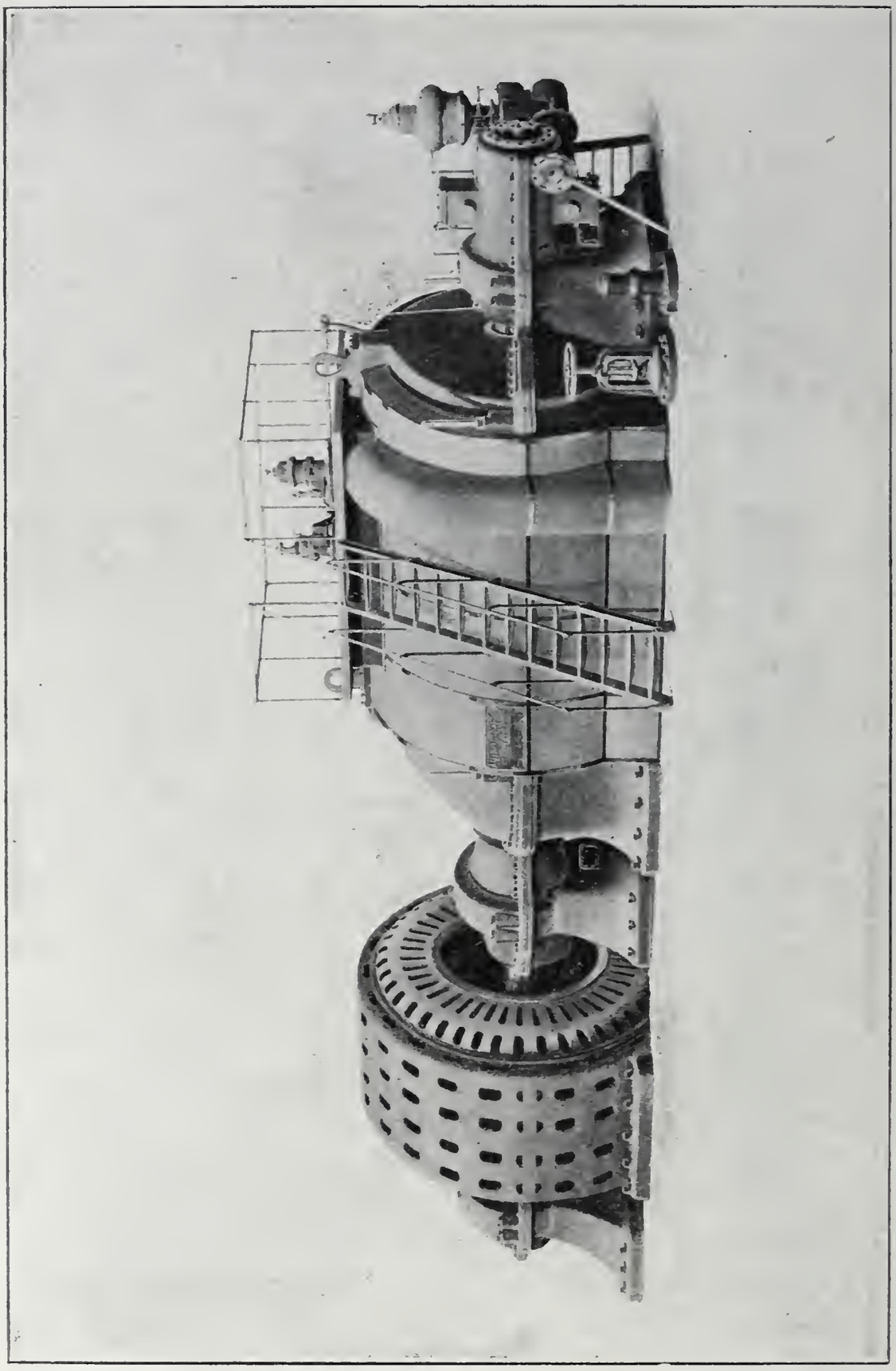


Fig. 4. 5500 K. W. Westinghouse Turbine and Generator.

forms were built and elaborate experiments made, the net result being the adoption of the Parsons turbine. The extent and magnitude of the turbine work at East Pittsburg shows that the choice of the Parsons turbine was a wise one.

Turbines from 20 to 8,000 horse power capacity are under construction at East Pittsburg. Some views of different turbines, testing and erecting shops may be of interest. Fig. 1 shows a 400 K. W. turbine unit, Fig. 2 a 750 K. W. unit, Fig. 3 a 1,500 K. W. unit and Fig. 4 a 5,500 K. W. unit, Figs 5 to 8 are views taken in the turbine testing and erecting shops of The Westinghouse Machine Company. The testing plant where all turbines are given thorough tests is well worthy of interest. Brake tests are made on all machines, and electrical tests where purchasers so desire. It is of interest to note that facilities are at hand to get brake loads of over 5,000 horse power. The brakes in use were developed by The Westinghouse Machine Company as a means of making economy and other tests requiring load with the utmost facility and accuracy.

In the Parsons turbine there are alternate rows of revolving and stationary blades, each row being a complete annulus. Both sets of blades are of practically the same shape, material, etc.; the heights of the rows of blades gradually increase towards the exhaust end of the turbine in order to accommodate the increased volume of the steam. The dimensions of the blades are given by theoretical calculations and the result of careful experiment.

By referring to the diagram, Fig. 9, it is seen that the stationary row of blades impinges a jet of steam on the moving row, the tendency being, of course, to turn the shaft. Further expansion then takes place in the moving set of vanes, and a jet issues from them, the reaction of which tends to turn the shaft again. Expansion takes place in both the moving and stationary blades, and we have both the impignment of the jets from the stationary blades as well as the reaction of jets from moving blades to turn the shaft. Steam velocities are very low in this type of turbine, so low that erosion of blading is negligible.

Fig. 10 gives a general view of the Westinghouse-Parsons turbine. The rotating part is seen to consist of a cylindrical element in which the moving vanes are secured. The vanes or

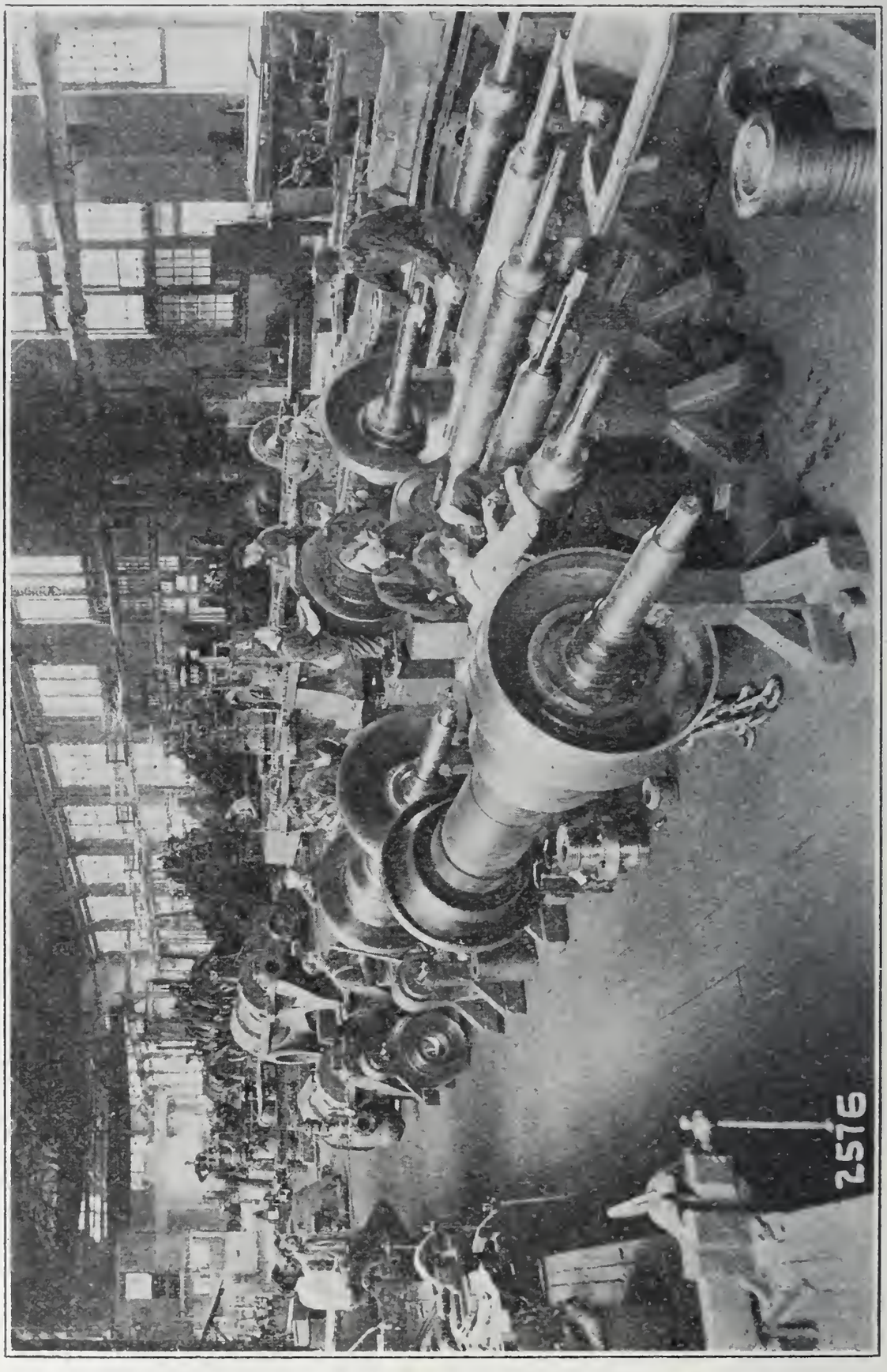


Fig. 5. View in Main Erecting Shop.

blades are inserted with the utmost ease and celerity, but when in place are as tight as if an integral part of the steel body or spindle in which they are inserted. This ease of insertion makes repairs easy. Cases have been known where expanding exhaust pipes have twisted the turbine cylinder out of line resulting in the damage of some blades; these have been repaired during the night and the turbine put into service as usual next morning. The damaged blades may simply be chipped out and machine operated as usual, if no repair material is at hand. The small model shows thoroughly the method of blading construction.

The turbine would have a strong axial end thrust towards the exhaust end of the turbine if it were not for the fact that balance pistons are put on the shaft, which have an equal and opposite end thrust. The leakage of these balance pistons is practically a negligible amount as compared with the total steam going through turbine, and what does occur is returned to the working steam at the next lower drum.

It is rather a curious phenomena that a grooved piston revolving in corresponding grooves in a cylinder forms an effective packing when revolving at high speeds. The balance pistons are grooved and fit in corresponding grooves in the cylinder of turbine. In Fig. 10 the balance pistons are shown at (P).

The passages (E) in Fig. 10 are equilibrium passages. They keep the pressure on the balance pistons just the same as on that part of the turbine which the pistons balance. It is noted that the turbine is built in three diameters; this is done simply because it is convenient; theoretically there could be any number of different diameters, or, on the other hand, there could be but one diameter.

At (T) Fig. 10 is a thrust bearing whose only use is to keep the spindle or rotating part in proper longitudinal adjustment; as the balance pistons counteract any end thrust, there is no duty whatever on the thrust bearing.

One of the features that seems to appeal very strongly to engineers, regarding Westinghouse turbines, is the fact that no cylinder oil is needed for internal lubrication. The latest great improvement in this line is the water-sealed frictionless gland which packs the shaft where it comes through the cylinder ends. These

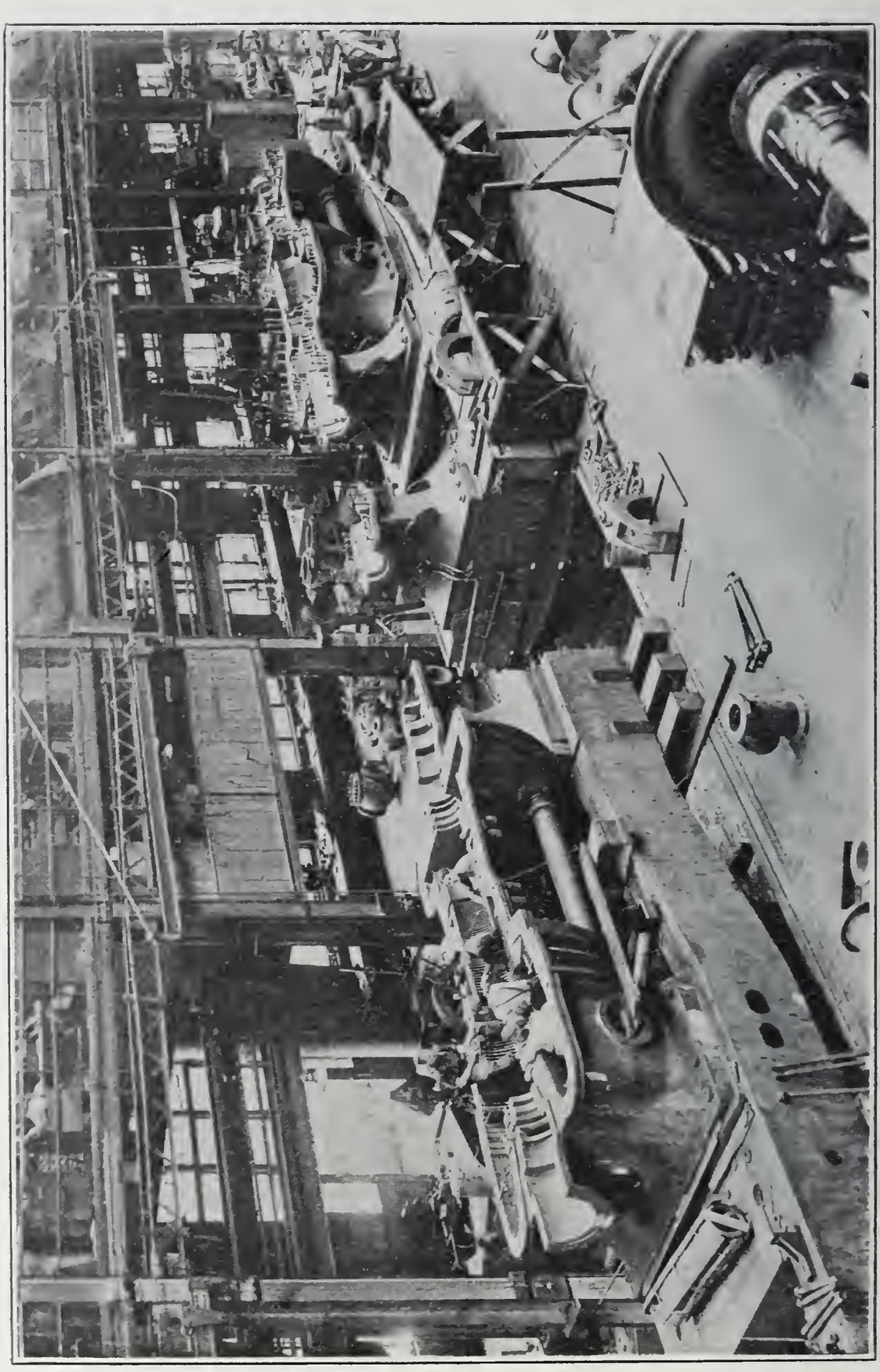


Fig. 6. 5500 K. W. Turbines in Course of Erection.

glands are absolutely leak-proof, need no lubrication whatever and are practically indestructible as regards wear, as there are no rubbing parts. The advantages of an engine discharging no cylinder oil into its own exhaust are apparent. Surface condensers may be used with a closed hot well system returning clean condensation to boilers without getting it aerated, consequently enabling the maintenance of a higher vacuum than would otherwise be possible.

The diagrammatic arrangement of governor is shown in Fig. 11. The lever (H) is oscillated from the end (K). The governor balls of course control the position of the point (F), so that the plane of oscillation of the small relay valve (A) is dependent on the position of the governor balls. The small relay valve controls the motion of the piston (B), which is directly connected to the main inlet valve, which is marked V in Fig. 10. When the plane of oscillation of the relay valve is low the main inlet valve opens wide conversely; when the plane of oscillation is high the steam inlet valve opens synchronously with the oscillation of the relay valve, but by a lesser amount, depending on the difference in plans of oscillation. Every part of the governing mechanism is in motion at all times so that there is no friction of rest to overcome. In the present standard Westinghouse turbines, the governor levers actuate an automatic secondary valve (Vs. in Fig. 10) as well as the main admission valve. The mechanism of the secondary valve is somewhat similar to the main steam inlet valve. This valve admits high pressure steam to the intermediate stage of the turbine, allowing abnormal loads to be carried. The Westinghouse turbines have carried 100% overload running condensing and 50% overload running non-condensing. This is done without abnormal changes in speed, so that a power plant equipped with these turbines would not have parallel operation endangered by a momentary overload of great magnitude.

This ability to carry heavy overloads, and to carry full loads with no vacuum is of prime importance to anyone desiring uninterrupted service for modern power stations. The flexibility of the turbine is not approached by any other form of steam prime mover. Absolutely no change is required in any Westinghouse

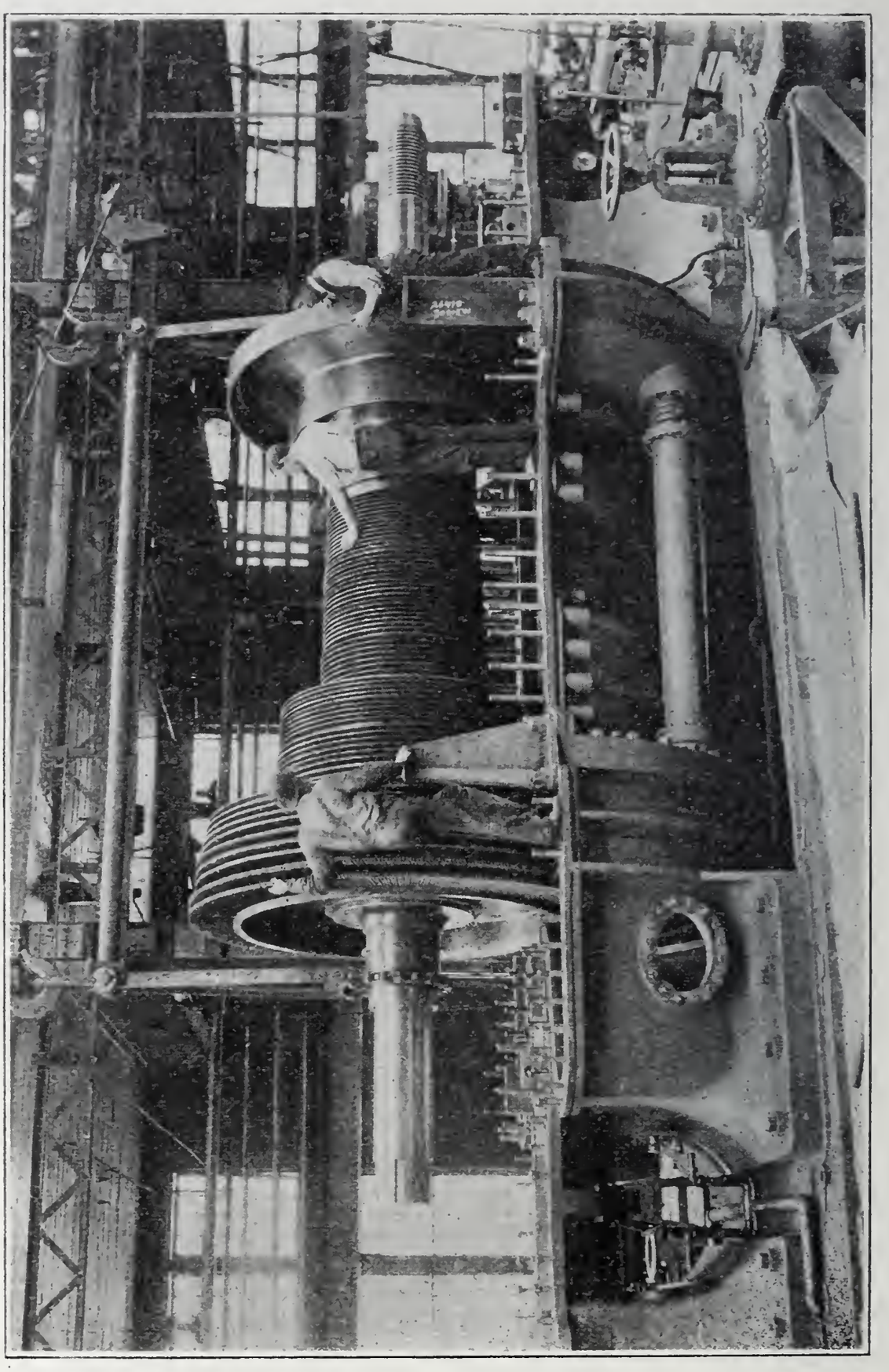


Fig. 7. Assembling a 5500 K. W. Turbine.

turbine of any size for running under all manner of conditions, such as high vacuum, low vacuum, no vacuum, etc. Of course, this infers that the steam pressure does not drop abnormally. It is generally necessary to the successful operation of large compound condensing engines without a vacuum to change the exhaust valve setting on the low pressure cylinder to conform to the conditions.

Parallel operation with the steam turbine is about as near perfection as can be attained. This motor has the ideal requirements for successful parallel operation, as the turning torque is uniform and the fly-wheel effect of the turbine and generator is such as to preclude erratic changes of speed due to electrical and mechanical harmonies. With the style of governor in use very close regulation may be obtained, less than 1½ per cent. between no loads and full load is practicable, though not desirable where paralleling with a rapidly fluctuating load.

Current technical literature has pretty well spread the idea that for passable economy the turbine, superheat, high boiler pressure and high vacuum must go hand in hand. With the Parsons turbine this is not a criterion, relatively excellent economy being given by machines operating under low vacuum and low boiler pressure. The following tests exemplify this.

Two groups of tests are given below, brake horse power being measured by the special brakes previously referred to. One group of tests was made on turbine No. 43, and shows economy for varying vacuums This engine is rated at 1,250 K. W., and is now being installed at the power house of the Interborough Rapid Transit Company of New York.

The other group was made on engine No. 28, which is rated at 400 K. W. This engine is in steady operation at Nyack, N. Y., at the plant of the Rockland Light and Power Company.

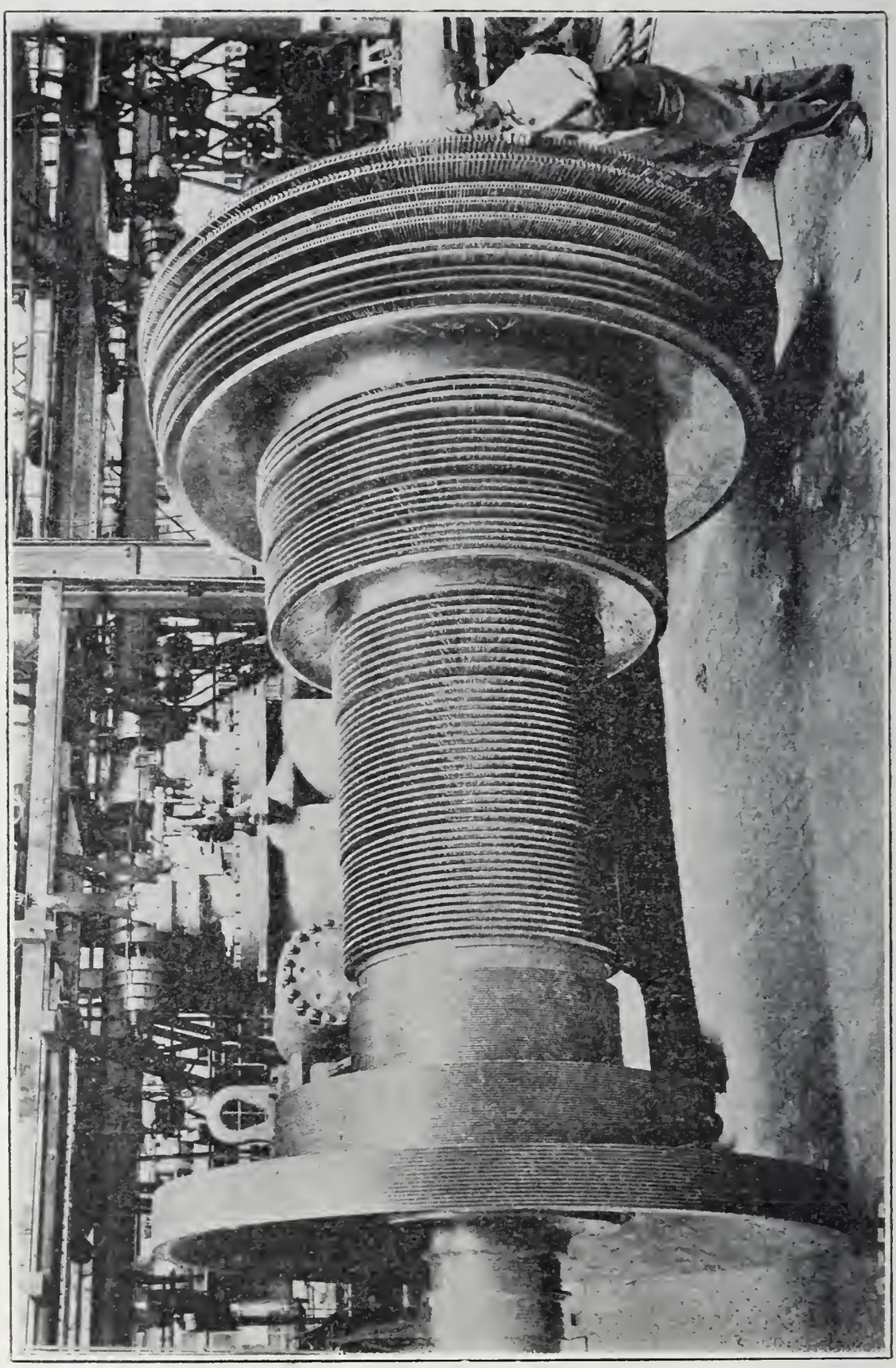


Fig. 8. Revolving Element of a 5500 K. W. Turbine.

Tests on Westinghouse Turbine No. 43.

1250 K. W.—1200 R. P. M.

Boiler pressure lbs. gauge.	Vacuum in inches of mercury referred to 30-in. barometer..	Superheat degrees Fahrenheit.....	Total steam condensed per hour.	Load in brake horse power....	Lbs. of steam per brake horse power per hour.	Test number....
146.4	25.01	None	28902	2008.	14.39	33
148.4	25.05	None	16809	1004.4	16.73	32
147.	26.01	None	28236	2002.3	14.1	34
148.9	26.05	None	16106	1007.	15.99	35
146.3	27.	2.3	27248	2005.3	13.59	27
145.9	27.	2.	21189	1499.7	14.13	28
148.7	26.95	2.2	15241	1004.	15.18	29

Tests on Westinghouse Turbine No. 28.

400 K. W.—3600 R. P. M.

Boiler pressure lbs. gauge.	Vacuum in inches of mercury referred to 30-in. barometer..	Superheat degrees Fahrenheit.....	Total steam condensed per hour.	Load in brake horse power....	Lbs. of steam per brake horse power per hour.	Test number....
125.6	26.	2.54	8939.5	580	15.41	3
124.9	26.02	None	7481.	457.	16.36	4
130.6	26.03	None	5834.	326	17.89	5

It must be borne in mind that the above results are for brake horse power.

The result given by turbine No. 43, as shown in test 33, is certainly very good. The production of a brake horse power on 14.39 pounds of steam, with as low a vacuum as 25 inches, shows the turbine to be an economical engine under low vacuum conditions. The increased economy, however, is noted as the vacuum rises.

Tests on turbine 28 show that good results may be attained under what might be termed bad "all around" conditions. The boiler pressure and vacuum are both low, yet a brake horse power is produced on 15.41 lbs. of steam.

The question as to whether superheat is a paying investment in any power plant seems to be still an open question, the conten-

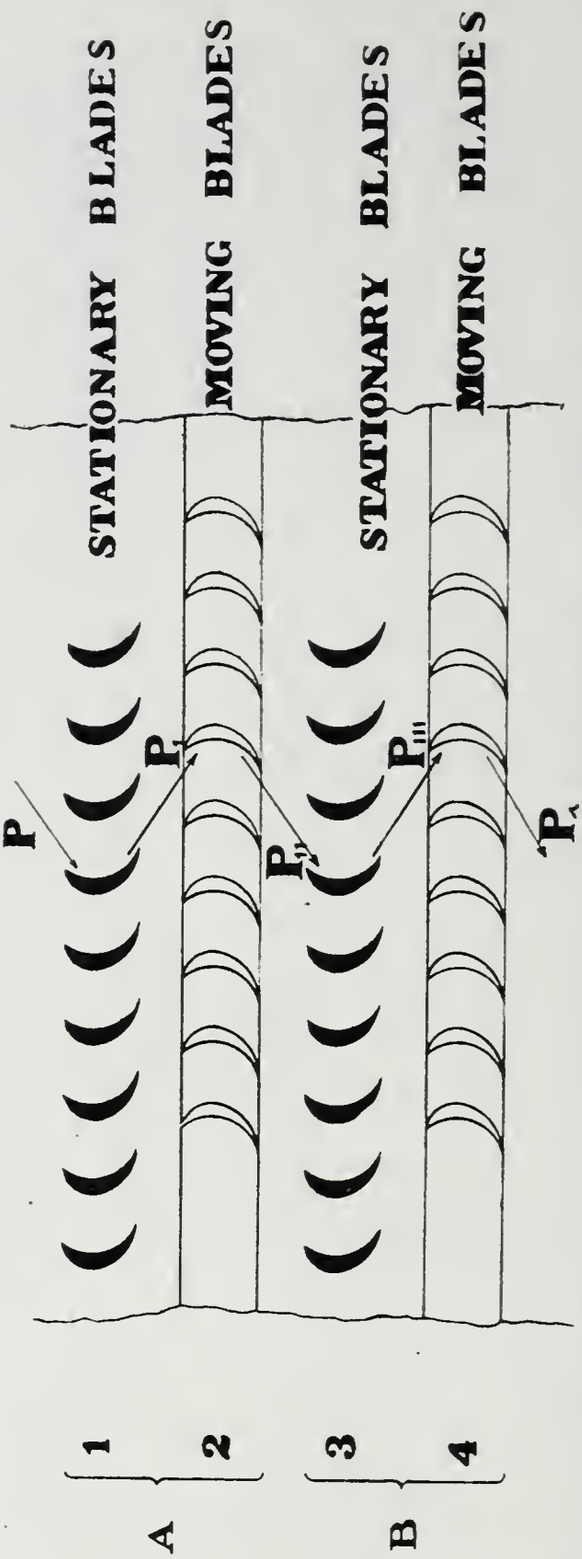


Fig. 9. Diagrammatic Representation of Buckets in Westinghouse-Parsons Turbine.

tion being that the extra cost of superheating combined with the depreciation of value on the extra outlay of apparatus, more than overbalances the decreased steam consumption of the engine equipment.

However, the marked increase in steam economy of the turbine shows that if superheating pays, the turbine offers better facilities for taking advantage of the resulting benefits than any other form of steam motor.

The following tests made by Messrs. Dean and Main, Consulting Engineers, Boston, on a 400 K. W. Westinghouse turbine, show the great increase in economy due to superheat. These tests were made at East Pittsburg at approximately 1¼ load:

Test number...	Lbs. of steam per brake horse power per hour.	Load in brake horse power...	Total steam condensed per hour.	Superheat degrees Fahrenheit.....	Vacuum in inches of mercury referred to 30-in. barometer..	Boiler pressure lbs. gauge.
	13.62	729	9928	None	28.01	153.6
	12.06	759	9157	104	28.01	150
	11.17	763	8520	182	28.08	150.2

The figure 11.17 is truly remarkable for an engine of this size. This represents an increase of economy of nearly 20 per cent. by superheating approximately 180 degrees Fahrenheit.

The operation of turbines without a vacuum has to be considered from two points of view.

First. Where the turbine is designed to operate without vacuum.

Second. Where the turbine is designed to operate with vacuum and has to operate in times of emergency for varying periods, without a vacuum.

To design a turbine to operate without a vacuum is a comparatively simple matter, and a machine of satisfactory efficiency may be easily built. Some idea may be gotten of the efficiency of a non-condensing turbine by reference to the following figures. These tests were made on a 1250 K. W. turbine, which had the shaft denuded of the lower pressure part of turbine. The results given by such a combination, while not as good as what could be expected from a machine

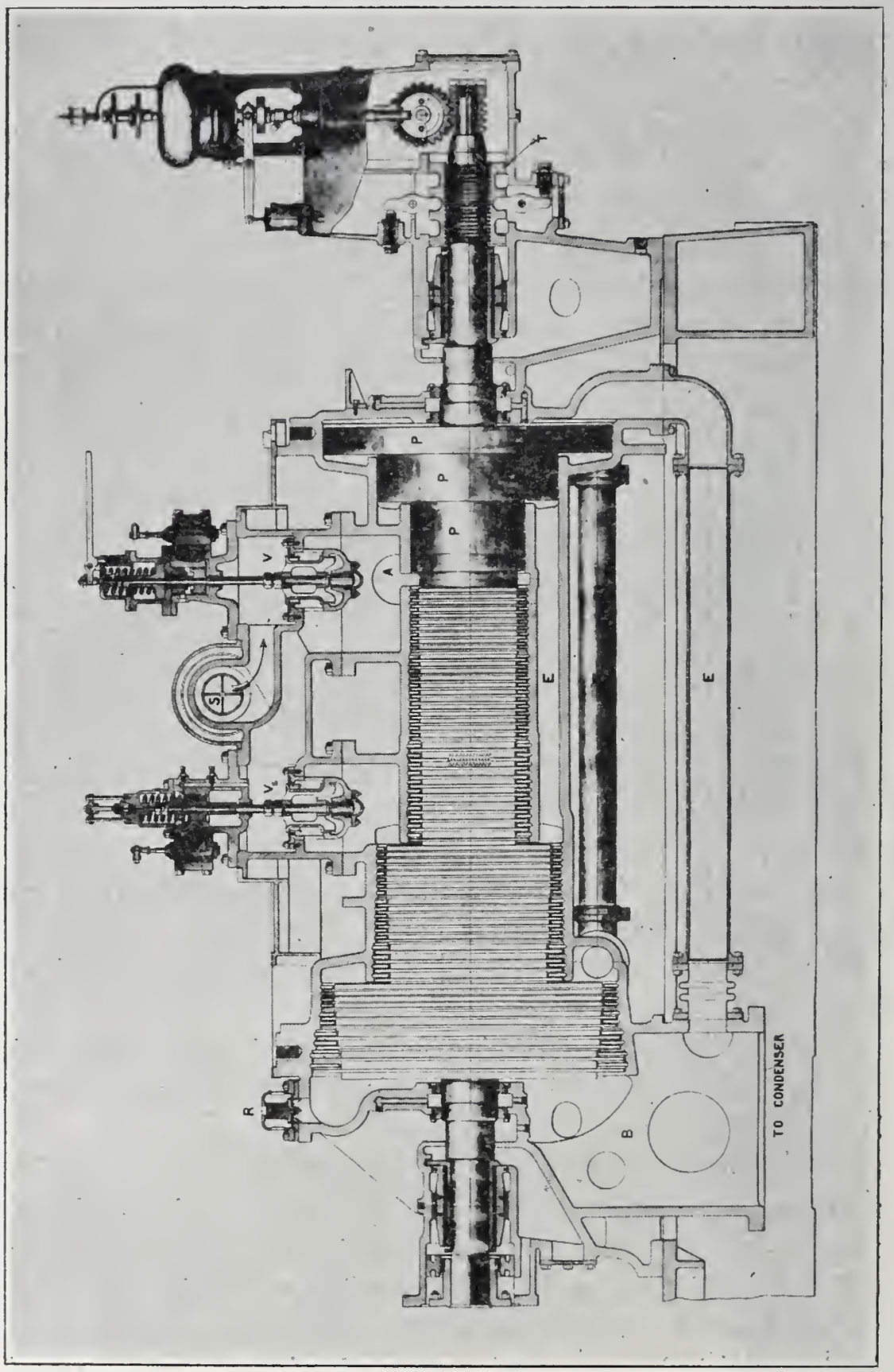


Fig. 10. Sectional View of Westinghouse Turbine.

designed especially for the conditions, nevertheless show that the non-condensing turbine has a broad field of usefulness.

Test of 1250 K. W. Condensing Turbine No. 43.

With high pressure part only in operation—1200 R. P. M.

Boiler pressure lbs. gauge.	Vacuum in inches of mercury referred to 30-in. barometer..	Superheat degrees Fahrenheit.....	Total steam condensed per hour.	Brake horse power.....	Lbs. of steam per brake horse power per hour.	Test number...
146.2	None	None	18672	660	28.3	72
145.5	None	None	23261	889.9	26.15	70
150.7	None	None	30338	1261	24.05	71

The figure 24.05 is by no means bad and represents about what a 750 K. W. turbine would do when designed for non-condensing operation.

The greatest test of the turbine designers' skill is the production of a turbine combination that will give the maximum efficiency when running condensing and give as nearly as possible, the best economy, when emergency demands non-condensing operation. The Westinghouse Machine Company has endeavored to meet the above qualifications in their turbines. The following figures show how well they have succeeded:

Test on Turbine No. 59.

750 K. W.—1800 R. P. M.

Boiler pressure lbs. gauge.	Vacuum in inches of mercury referred to 30-in. barometer..	Superheat degrees Fahrenheit.....	Total steam condensed per hour	Brake horse power.....	Lbs. of steam per brake horse power per hour.	Test number...
150.9	27.85	99.72	20202	1554	12.99	11
151.4	28.01	99.07	13808	1115.1	12.38	12
150.8	28.07	102.6	9450	712.	13.27	19
149.4	None	85.33	36248	1544	23.4	24
153.5	None	93.9	18308	761	24.06	22
144.5	None	96.68	12065	397.7	30.33	23

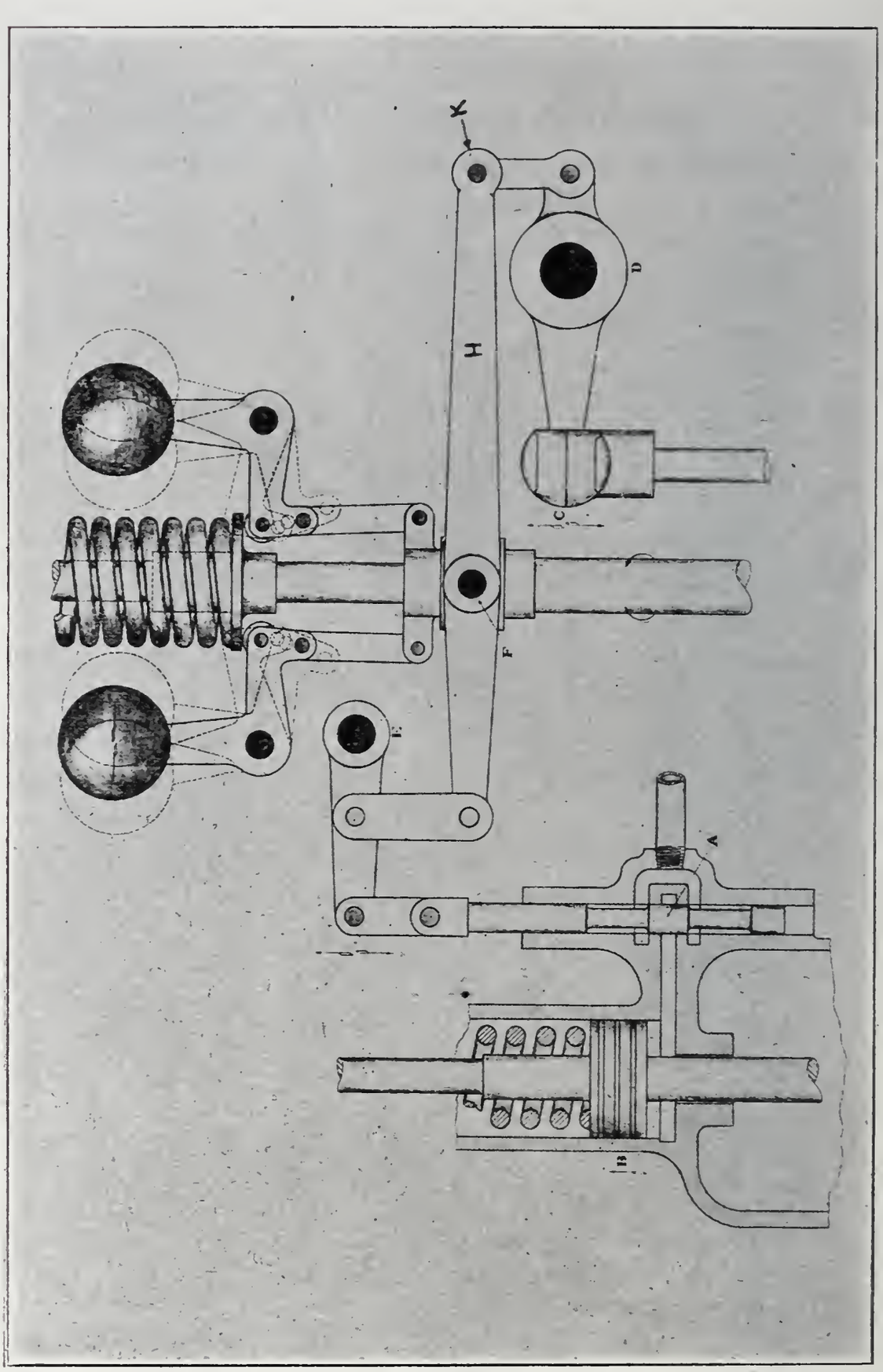


Fig. 11. Diagrammatic Arrangement of Governor.

The above figures show that the condensing turbine, when running without a vacuum, is a fairly economical engine. With saturated steam and no vacuum, the above turbine produced a brake horse power on about 28 pounds of steam per hour.

It must be borne in mind that the above engine was of the standard condensing type and that absolutely no change of any character was made to meet the different conditions of operation. The above machine is part of the Boston Navy Yard equipment.

Fig. 12 shows the results of the tests in a graphical manner. Other tests are incorporated as well, showing some of the economy characteristics. The great overload capacity, due to the secondary valve, is well illustrated by these curves. This valve comes into operation at the point of inflection of the respective curves. Referring to curve D, it is noted that from about 500 to 2100 brake horse power, the water rate per brake horse power is under 14 lbs. and even goes as low as 12.39.

From the foregoing, it is evident that the Westinghouse-Parsons steam turbine as an operative mechanism, is eminently economical, under all conditions of operation and that its extreme flexibility recommends it to the first place among steam prime movers.

Assuming the validity of the above conclusions, there remains the following considerations other than steam economy and flexibility, which, if fulfilled by the turbine, in a favorable manner, put this type of engine forward as one of the most useful and applicable developments of modern engineering. The considerations above mentioned, would seem to arrange themselves in natural order, as follows: 1st. Reliability. 2nd. Permanence. 3rd. Economy of maintenance. 4th. Economy of attendance. 5th. Economy in the use of oil. 6th. Economy as regards foundation and building expenses. 7th. Celerity and ease of erection.

Reliability. Many articles have come to the attention of engineering readers with reference to the respective merits of the steam turbine and reciprocating engines. Nearly all these

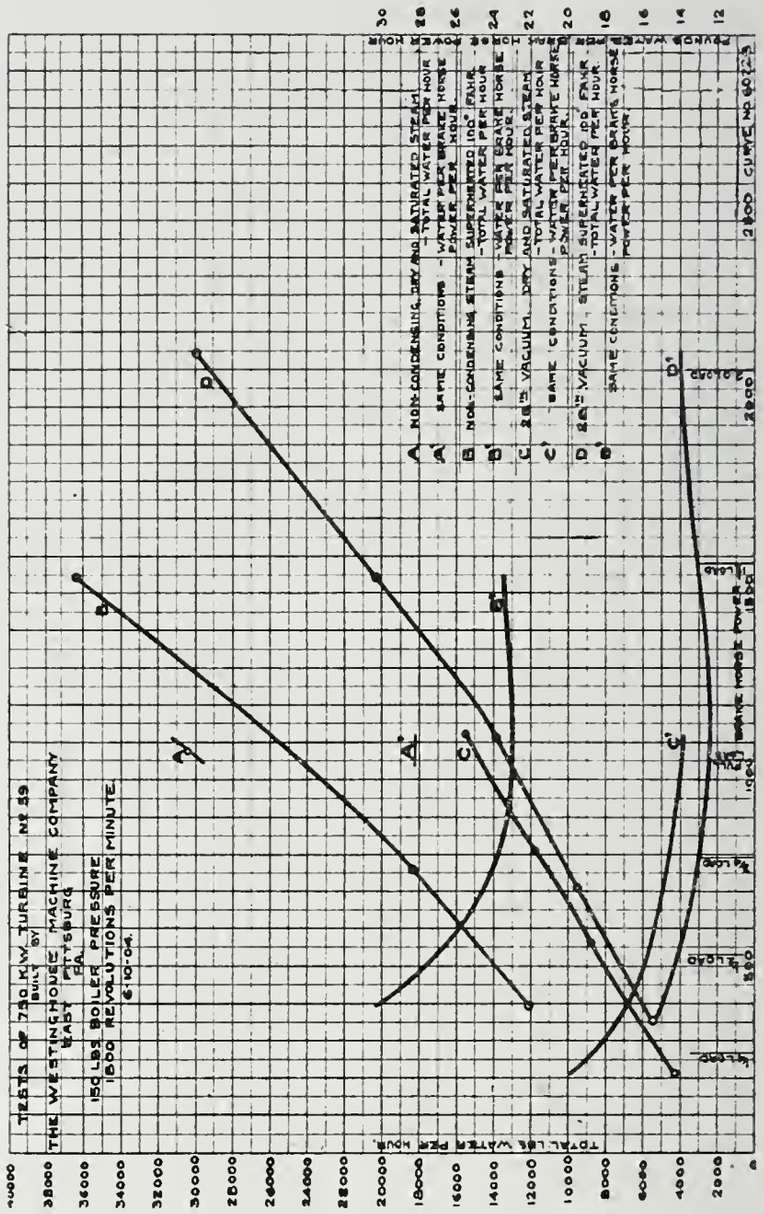

TESTS OF 750 K.W. TURBINE Nº 59
BUILT BY
THE WESTINGHOUSE MACHINE COMPANY
EAST PITTSBURG PA.
150 LBS BOILER PRESSURE
1800 REVOLUTIONS PER MINUTE.
6-10-04.
A NON-CONDENSING DRY AND SATURATED STEAM
A' SAME CONDITIONS - TOTAL WATER PER HOUR
- WATER PER BRAKE HORSE POWER PER HOUR.
B NON-CONDENSING STEAM SUPERHEATED 100° FAHR.
- TOTAL WATER PER HOUR
B' SAME CONDITIONS - WATER PER BRAKE HORSE POWER PER HOUR.
C 28½ VACUUM. DRY AND SATURATED STEAM.
- TOTAL WATER PER HOUR
C' SAME CONDITIONS - WATER PER BRAKE HORSE POWER PER HOUR.
D 28½ VACUUM. STEAM SUPERHEATED 100 FAHR.
- TOTAL WATER PER HOUR.
D' SAME CONDITIONS - WATER PER BRAKE HORSE POWER PER HOUR.
2000 CURVE Nº 6023
TOTAL LBS WATER PER HOUR
BRAKE HORSE POWER

Fig. 12.

articles dwelt at length on the question of steam economy, and few of them touched on the problem that interests the engineer engaged in power generation to the greatest extent. One of the prime merits of the turbine is its reliability. Accidents, of course, have happened to turbines; practically all the trouble that has been associated with a few of the Westinghouse turbines was attributable to one source. The cause of this has been eliminated by proper alteration of design. The best evidence of reliability, in turbines, is the duplication of a single turbine installation by another, after the performance of the first has been carefully noted. As an example of this we might name The Yale & Towne Manfg. Co., Westinghouse Air Brake Company, Hartford Electric Light Company, and the De Beers Mining Co., of Kimberly, South Africa, who after operating two 1000 K. W. machines for nearly two years, have ordered a 1500 K. W. unit.

It is a very common occurrence for a turbine to have uninterrupted runs of many weeks' duration. A Parsons turbine, built by Brown, Boveri & Co., of Baden, Switzerland, is credited with an uninterrupted run of a year's duration.

Permanence. As steam velocities are very low there is no danger of blade erosion in the Parsons turbine. The bearings do not wear by any appreciable amount. Mr. F. A. Waldran calls attention to this in his recent paper before the A. S. M. E. Repeated tests show that the turbine does not deteriorate as regards efficiency, after long operation. This is far from true, with the reciprocating engine, where the parts, such as valves, piston rings, etc., all tend to wear and make the economy worse after lengthy operation. As the bearings and blades are about all that could possibly wear excessively, we may conclude that wear is a minimum. Cases have been known where slugs of water have passed through turbines without injuring them in the least. It is probable that turbines in this respect have stood punishment that would certainly wreck reciprocating engines.

Economy of Maintenance. Experience has shown that the repairs on a turbine plant are very low. This is perfectly natural when the simplicity of the outfit is taken into consideration. The generators have shown remarkable ability

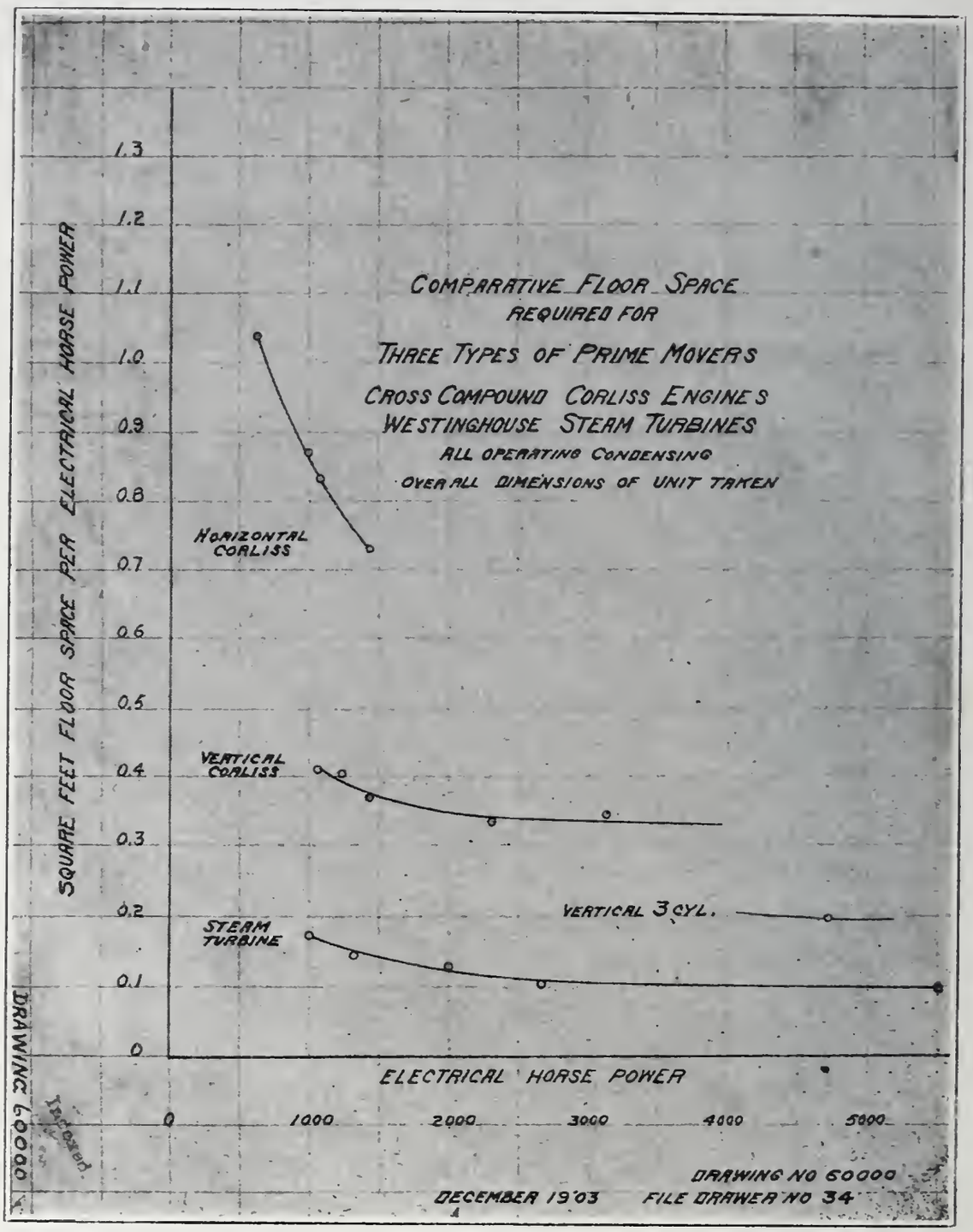


Fig. 13. Relative Floor Space Occupied by Different Forms of Prime Movers.

to stand heavy overloads without excessive heating and consequent damage.

Economy of Attendance. The simplicity of the turbine makes the cost of attendance a minimum. As an example, the writer can cite a case where a switch-board attendant who has 12 rotary converters to look after, also acts as engineer and switch-board attendant for a 400 K. W. Westinghouse turbine. The rotary converters are driven from a water power plant some miles away.

Economy in Use of Oil. The Westinghouse turbine uses no cylinder oil, so that a marked reduction of expense over reciprocating engines is due to this item alone. The method of journal lubrication is to use an oil pump, driven by the turbine itself, to circulate oil from a central reservoir through the bearings, the oil being returned to the reservoir. Returns from a large number of users of Westinghouse turbines, show that the turbines use about $\frac{1}{4}$ gallon of oil per Kilo-watt year, or it may be roughly stated that the cost of oil for a 400 K. W. turbine, in steady operation, is about 5 cent a day. Such results can not be approached by reciprocating engines.

Economy as Regards Foundation and Building Expenses. To the engineer familiar with the ponderous foundation for reciprocating engines, a steam turbine foundation seems rediculous on account of the little there is of it. All that is needed is a permanent foundation, strong enough to support the dead weight of the turbine outfit. As all motion is that of rotation of balanced cylinders, no foundation bolts are required. Fig. 13 shows the relatively small floor space needed for installing Westinghouse turbines. This, of course, decreases the expense of building to a proportionate extent.

The maximum height above the floor level of a 5500 K. W. outfit is only 14 feet, a great contrast to the towering frames of large reciprocating engines.

Celerity and Ease of Erection. It is very often distressing for a purchaser to have to wait for periods of varying length of time for the operative stage of a machine, after it has been delivered to him. Turbines due to their compact form and simplicity are very easy to erect, practically all

that need be done is to carefully level and align the turbine to condenser and steam pipes. It is the custom of the Westinghouse Machine Company to ship the turbine complete on its bedplate, where the size is not prohibitive.

The writer knows of a 400 Kilo-watt turbine having been put on its foundation, connected to condenser and made ready to run in twenty-seven hours.

In conclusion we might say that the Westinghouse-Parsons turbine, as it stands to-day, is a machine intended to withstand the heavy requirements of modern power generation, and that it is essentially the machine of to-day and need not be relegated to the future. Its worth has been proven by years of service under the most exacting conditions. Lord Kelvin is quoted as considering the steam turbine as the greatest engineering development of the last century.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and forty-ninth regular meeting of the Engineers' Society of Western Pennsylvania, was held at the Society's House, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, November 15th, 1904, at 8 P. M., President J. M. Camp in the chair.

The minutes of the preceding meeting were read and approved.

The Board of Direction report that they had approved of the following applications for membership and present the same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
H. A. BERG,	Carnegie Hotel, Munhall, Pa.	Wm. Ahlen, Wm. H. Baily, J. M. Camp.
A. S. CAMACHO,	1501 Park Bldg., Pittsburg, Pa.	T. F. Webster, J. Merrill, G. T. Barnsley.
T. P. DAVIES,	P. O. Box 469, Duquesne, Pa.	Wm. Ahlen, Wm. H. Baily, J. M. Camp.
C. F. DRAKE,	Superintendent, 5700 Hays Street, Pittsburg, Pa.	Morris Knowles, Geo. T. Barnsley, Jas. M. Camp.
F. E. FIELD,	Engineer, 618 N. St. Clair Street, Pittsburg, Pa.	Morris Knowles, M. M. Manneese, J. M. Rice.
HERBERT HALLSWORTH,	215 Biddle Ave., Wilkinsburg, Pa.	S. R. Bachtel, P. A. Young, H. D. Lufkin.
GEO. K. HAMFELDT,	Rankin, Pa.	Wm. Ahlen, Wm. H. Baily, J. M. Camp.
E. D. LELAND,	168 Craig St., Pittsburg, Pa.	Wm. M. Welch, Paul L. Hay, Samuel Diescher.

JAS. SCOTT McBRIDE,	Carnegie Steel Co., Clairton, Pa.	Geo. L. Collord, J. G. Lanning, Chas. H. Rich.
DONALD McI. NAISMITH,	6312 Butler St., Pittsburg, Pa.	Samuel Diescher, Alfred Diescher, C. H. Sample.
LEONARD W. O'BRIAN,	215 Smithfield St., Pittsburg, Pa. h., 217 Edgewood Ave., Dayton, Ohio.	Samuel Diescher, G. E. Flanagan, G. T. Barnsley.
RICHARD P. THATCHER,	325 Spahr St., Pittsburg, Pa.	J. L. Klindworth, G. E. Flanagan, Alex. L. Hoerr.

It was moved, seconded and carried that the Secretary cast a ballot electing these applicants to membership.

PRESIDENT—Is the Committee on the death of Mr. Arthur Kirk ready to report?

Mr. Samuel Diescher, Chairman of the Committee reads report on Mr. Kirk's death as follows:

Arthur Kirk, a member of this society since March, 1882, died on September 26, 1904, in the 80th year of his age, at his residence in Sharpsburg. Surviving him is his widow with four children and ten grandchildren.

Born in Lanarkshire, Scotland, as was his wife, Mary Lawrence, Mr. Kirk came here in 1839; they were married in 1848 and lived in Allegheny. He worked in the cotton mill, then kept a grocery store on Federal St., and later participated in the rapid development of petroleum up the Allegheny river.

In 1867 he entered into business, dealing with high explosives, and later established the manufacture of dynamite and powder, and when he retired from business last year, the firm of A. Kirk & Sons had extensive interests in blasting powder works elsewhere also.

Mr. Kirk was ardent in all social relations and his personal efforts for public improvements were exceeded by no man's. He was positive as a United Presbyterian and Prohibitionist, and was a leading member in the Robert Burns' and other Scottish societies. The local civil war veterans knew him to do him honor as their active friend, and the town's children loved him. His example in advancing Sharpsburg as a municipality

brought in other strong men to aid, but his was ever the indefatigable working.

Mr. Kirk very early espoused the cause of river improvement by the general government, and he was the inventor of a movable dam, as were others of us makers of such designs for which there was a call. But some there were who wanted no interference with the river's regime and its irregular navigation attended with extremes of profit and loss, and bitter were they if they could dub the advocate "a patent monger." Of course, they subsided seeing "the light of expediency," but only quickly to emerge claiming championship when the first dam was completed.

But of Arthur Kirk as a champion of good roads in Pennsylvania most of us here have the recollection. He worked and spent his money in printing to enlighten the people and the legislature, singly offering the draft of a general road law at every session. His appeal to our society was to join in demanding system in the laying out, the making, and the up-keeping of the public roads, and particularly that all the work should be directed by engineers. His travels in Europe had for their main purpose the study of foreign institutions promoting permanent highways. At our Pittsburg Exposition he twice exhibited the large sets of typical paving blocks, etc., he had imported from several countries to teach our people more than they wanted to know.

It is a satisfaction to record that some of us aided him undeterred by "the silent smile of slow disparagement" in opposition, and wrote into the Society's proceedings, descriptive and suggestive reports for which the normal object lessons were given us by Arthur Kirk; and now again we see his original idea forming a movement that the road-making be directed by township and county engineers under the revolutionary system warranted by the new legislation, allowing state, county and township pecuniary co-operation.

The family of Arthur Kirk prize the autograph letter of condolence they have received from Andrew Carnegie, and we may touch this grace of sympathy in adding appreciation as both men have been among the oldest membership of our society,

to recall their following each other in doing youthful manual labor for the bare living wages afforded at that cotton mill that was soon to be a decayed local industry, but no doubt gave training for something better. And we may couple the two men, tho' apart in years, as having signally the inborn adaption and tenacity of purpose of their race, but with the pursuit of an ideal in their careers—the uplift of humanity.

Honor to Arthur Kirk and peace to his ashes!

F. Z. SCHELLENBERG,
CHAS. DAVIS,
SAMUEL DIESCHER,
Committee.

It was moved, seconded and carried that these resolutions be entered in the minutes of the Society and a copy sent to the family.

PRESIDENT—Is the Committee ready to report on how Mr. Sibert procured his invitation to read a paper before this Society?

REPORT OF COMMITTEE ON MAJOR WILLIAM L. SIBERT, UNION BRIDGE COMPANY, ENGINEERS' SOCIETY OF WESTERN PA.

PITTSBURG, PA., NOVEMBER 10, 1904.

MR. PRESIDENT AND MEMBERS OF THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

Gentlemen—Your committee appointed to inquire into the truth of the charges made by the attorneys of the Union Bridge Company, embodied in Section Eight of the brief filed with the office of Secretary of War, entitled, "In the matter of Union Bridge across the Allegheny River, at Pittsburg, Pa.," namely:

"Section Eight. Some time in the first half of the year 1902, Captain Sibert prepared an address upon 'Full Use of the Rivers at Pittsburg and the Removal of Obstructions to Such Use,' and somehow or other procured an invitation to read the address before the Engineers' Society of Western Pennsylvania, which he did, at its meeting upon September 23rd, 1902. In this address, he proposed the rebuilding or raising of all bridges over the Allegheny River between the cities of Pittsburg and Allegheny,

and presented detailed plans showing how he would do the work at each bridge, etc."

We submit the following facts:

1. Mr. Richard Hirsch, Chairman of the Program Committee, requested Major Sibert by letter to read a paper, and was not approached directly or indirectly by Major Sibert, requesting the privilege to force his views upon the engineers or the public.

2. Major Sibert was one of the several who were requested by Mr. Hirsch to present papers on the different phases of the bridge and navigation problem of the Allegheny River at Pittsburg, and on the same evening that his paper was read, others, bearing on the same subject, were presented.

3. Major Sibert was not a member of our society at the date the invitation was extended to him, July 7th, 1902, but is now an acceptable member.

4. The brief for Union Bridge Company published in the Pittsburg Gazette of October 8, 1904, so far as it reflects on Major Sibert's relations to this Society, past and present, and the members of the Society, is wholly untruthful, misleading, and did not emanate from the pen of a gentleman seeking the truth.

5. The circumstances leading up to Major Sibert receiving an invitation to read a paper, are clearly set forth in Mr. Richard Hirsch's letter of November 5th, 1902, addressed to Mr. E. K. Morse, a copy of which is attached.

6. We feel it the duty of this Society to ask the Chief of Engineers of the War Department, General Alexander MacKenzie, to strike from the records of his department, all that part of the brief reflecting on Major Sibert and this Society, and to return the said report to those drafting same, for that purpose.

7. We request that a copy of this report and the Society's action on same be sent to General MacKenzie.

All of which is respectfully submitted.

E. K. Morse, *Chairman.*
Samuel Diescher,
H. J. Lewis,
Committee.

PITTSBURG, PA., JULY 7, 1902.

CAPTAIN WILLIAM L. SIBERT,
United States Government Engineer,
Federal Building, Pittsburg, Pa.

Dear Sir—At the September meeting of the Engineers' Society of Western Pennsylvania, the Program Committee will present a paper on the construction of the new double deck bridge of the P. R. R., crossing the Allegheny River, in this city.

In connection therewith, we should be very much pleased to have you contribute a short paper or article in regard to the Restrictions or Regulations imposed in the construction of such structures, by the United States Government.

Any matter which you might be pleased to offer in regard to height and width of spans, or the proposed raising of bridges on our local rivers, or anything in regard to Harbor Lines, would add much interest to the discussion of this subject at our meeting and would be very acceptable to the Program Committee.

Trusting that I may have your favorable reply, I am,

Very truly yours,
RICHARD HIRSCH,
Chairman Program Committee.
1318 5th Ave., Pittsburg, Pa.

PITTSBURG, PA., JULY 22, 1902.

CAPTAIN WILLIAM L. SIBERT,
United States Government Engineer,
Federal Building, Pittsburg, Pa.

Dear Sir—I am very much pleased to have your kind favor of July 8th, in which you state it will be a pleasure to you to contribute a paper on the question of Regulations imposed by the United States Government, in the construction of bridges over our local rivers.

This will be a valuable addition to our program for our meeting, and I wish to thank you very much for the kindly interest you are taking in the work of the Engineers' Society of Western Pennsylvania.

At your earliest convenience, I would be pleased to have you send me a very brief synopsis of your paper, for our use in issuing the announcements for the meeting and subjects for paper.

This synopsis would merely mention a few of the sub-divisions or headings of your subject matter.

Very sincerely yours,

RICHARD HIRSCH,
1318 5th Ave.,
Pittsburg, Pa.

PITTSBURG, PA., JULY 22, 1902.

MR. E. K. MORSE,
904 Carnegie Bldg., Pittsburg, Pa.

Dear Sir—At the September meeting of the Engineers' Society, Mr. E. A. Amaden, of the American Bridge Co., will read a paper on the Construction of the New Double Deck Bridge of the P. R. R. in this city, and Captain William L. Sibert, of the United States Corps of Engineers, has kindly consented to give us a paper on the Government Restrictions and Regulations, in the matter of height of bridges, width of spans, etc.

In connection with this subject, we would be very much pleased to have you contribute a short paper or article on this general subject of bridges, crossing our local rivers particularly, in the matter of height, width of spans, and other matter pertaining thereto. This is a subject in which I know you are much interested, and we would like to have you write us a short paper for this meeting.

Hoping to have your favorable reply, and thanking you in advance for any information you may be pleased to give us, I am,

Very truly yours,

RICHARD HIRSCH,
Chairman Program Committee,
1318 5th Ave., Pittsburg, Pa.

PITTSBURG, PA., AUGUST 2, 1902.

MR. RICHARD HIRSCH,
Chairman Program Committee, Engineers' Society of Western Pennsylvania,
1318 5th Ave., Pittsburg, Pa.

Dear Sir—In compliance with your request of July 22, 1902, the following is a brief synopsis of the short paper that I will contribute at the September meeting of your society:

The function of the rivers in maintaining Pittsburg's present industrial supremacy.

Rules and Regulations concerning the bridging of navigable waters.

The Harbor of Pittsburg:

1. Its full use and obstructions preventing such use.

2. A preliminary study of the practicability of removing such obstructions.

Very respectfully yours,

WILLIAM L. SIBERT.

PITTSBURG, PA., NOVEMBER 4, 1904.

MR. RICHARD HIRSCH,

5634 Margaretta St., Pittsburg, Pa.

Dear Sir—Enclosed you will find copies of correspondence, respecting the article that Major Sibert read before the Engineers' Society, which unfortunately does not contain the letter of July 8th, written by Major Sibert, and which I have not as yet been able to obtain.

I wish to know how it came about that Major Sibert was requested to read a paper, and if directly or indirectly his name was suggested to you, or did you introduce this subject first yourself? According to an article which appeared in the Pittsburg Gazette, of October 8th, it would appear that Major Sibert availed himself of this opportunity to force himself on the public.

I am appointed chairman of a committee of three to lay all the facts before the next meeting of the Engineers' Society of Western Pennsylvania, and any light you can throw on the subject will be appreciated.

Yours truly,

E. K. MORSE.

PITTSBURG, PA., NOVEMBER 5, 1904.

MR. EDWIN K. MORSE,

Civil Engineer,

Farmers Bank Bldg., Pittsburg, Pa.

Dear Sir—I have your letter of November 4th asking me how it came about that Major Sibert was requested to read a paper before the Engineers' Society, and enclosing copies of letters written by me in reference to same.

In reply thereto I would state that at the June meeting (1902) of the Society we presented a number of papers describing the new terminal improvements of the Pennsylvania Railroad. These papers covered the several subjects: Power Plant, Approaches and Site, Design of Station, and Switches and Signals. The Program Committee has also arranged with Mr. E. A. Amaden to read a paper at this same meeting, describing the new double deck bridge of the Pennsylvania Railroad crossing the Allegheny River at Eleventh St. From reasons which I do not now recall, Mr. Amaden was unable to fulfill his engagement and the presentation of his papers was postponed until the September meeting.

As it had been our custom during that year to have at each meeting three or four papers dividing the general topic of discussion into as many subdivisions, and as we now found that we had but one paper provided for the September meeting, we looked about for others bearing on the same general subject, and procured several additional papers, all of which appear in the proceedings of the Society for the month of October, 1902. It was in connection with this work that I wrote to Major William L. Sibert, who was then a total stranger to me, stating that we had arranged for a paper describing the new Pennsylvania Railroad bridge and asked him to contribute a paper touching upon the restrictions imposed by the United States Government, regulating the construction of such structures, and requested the presentation of any matter relating to the height and width of spans, the proposed raising of bridges on our local rivers or anything that would add interest to the general subject. This is the substance of my letter of July 7, '02.

In my letter of July 22, 1902, addressed to Major William L. Sibert, I acknowledged receipt of his letter of July 8th, in which he stated that he would comply with my request and would read a paper on the subject under discussion. Unfortunately, I have destroyed Major Sibert's letter of July 8, 1902, together with all other papers relating to the work of the Program Committee for that year. I do not recall the substance of the letter any more than to say it was a favorable response to my request.

From the foregoing you will see that it was in response to my solicitation that Major Sibert read the paper referred to. He was a total stranger to me when I first addressed him and I did not have the pleasure of meeting him until the September meeting of the Society. He was not a member of the Society at that time, in fact the greater portion of the best papers that year were read by non-members. As my memory serves me Major Sibert's name was mentioned to me by Mr. Emil Swensson in answer to my inquiry as to where I might find a man in a position and willing to read a paper on this subject. This occurred during a conversation at one of the regular meetings of the Society. I called Mr. Swensson by 'phone this morning to verify this impression and he replied that he did mention Major Sibert's name in this connection and under the circumstances given above. I fully believe that Major Sibert in reading this paper was actuated by no other motive than this,—that having a subject of general interest to the engineering profession, he felt that he could present a paper for the occasion and responded to my invitation the same as would any engineer under similar circumstances.

If I can be of any further service to you in this connection, either by attending the meeting of your Committee or otherwise, please advise.

Very truly yours,

RICHARD HIRSCH,
Chairman Program Committee, 1902.

After discussion the following motion was made and passed:

"That the report of the Committee be accepted and that a copy of the report, together with the evidence, be sent at once to General MacKenzie, Chief Engineer of the U. S. Army, and 72 hours after copies are sent him, copies be sent to the daily papers."

PRESIDENT—The next business is the report of the Nominating Committee:

MR. JAMES M. CAMP, *President,*
The Engineers' Society of Western Pennsylvania,
%Duquesne Steel Works,
Duquesne, Penna.

DEAR SIR: In accordance with Article III, Section 1, of the By-laws, you appointed at the October meeting a Committee

to nominate officers for the Society and to report to the Society at the regular November meeting.

The Committee has given careful consideration to the duties which have devolved upon it. Especial attention was given to the selection of a Secretary. It was felt that the increased membership and the increased activities of the Society require a high grade of supervision of the work of the Secretary's office. The Committee felt also that the further development and prosperity of the Society depends in a large degree upon the efficiency with which its affairs are conducted. The Committee has selected a man whose education, ability and interest in the Society are believed to fit him especially for this work. It is expected that he will give general direction to the affairs of the Society, being accorded ample assistance for conducting the routine work of the office through increased appropriations for this purpose by the Board of Directors. The Society now has a surplus of several thousand dollars a year, a part of which should be devoted to the increasing of its efficiency.

It is proper to add that the present Secretary, Mr. Ridinger, stated to the Committee that his other duties were such that he can no longer continue as Secretary of the Society.

The nominations of the Committees are as follows:

SAMUEL DIESCHER, ... *President.*
S. M. KINTNER, ... *Vice President.*
GEO. T. BARNSLEY, ... } *Board of Directors.*
MORRIS KNOWLES, ... }
J. L. KLINDWORTH, ... *Secretary.*
A. E. FROST, ... *Treasurer.*

For the Committee.

H. J. LEWIS,
W. A. BOLE,
H. W. FISHER,
C. B. ALBREE,
Per
CHAS. F. SCOTT,
Chairman.

PRESIDENT—If there is no further business we will have the paper of the evening, by Mr. H. G. Balcom, on "Design of a Steel Water Flume."

DESIGN OF A STEEL WATER FLUME.

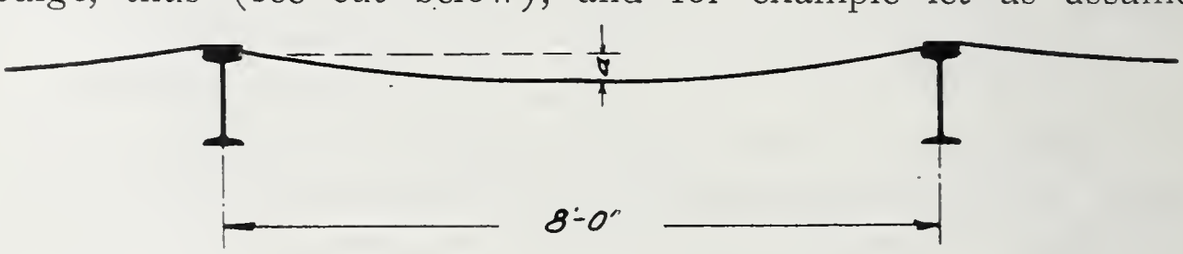
BY MR. H. G. BALCOM.

The subject concerning which I wish to speak to you to-night is a steel water flume of approximately 450 sq. ft. cross-section and more than 1,000 feet long.

When this subject presented itself to me a little less than a year ago, not only was I greatly interested in it, but also several of the other men in the office. It certainly possessed novelty, for none of us had ever approached such a subject before. About this time Mr. Lyons asked me to prepare a paper on some structural subject, and I thought perhaps it might interest you also to spend a short time in tracing with me one or two lines of possible development.

As far as I know, no steel flume of anything like these dimensions had ever been built. Some small ones have been built in the West, but they were so much smaller that their treatment would not apply to one of these dimensions.

The first scheme that would suggest itself would be an open box framed of beams and channels and lined with plate. This cross-section would require a box 30′ wide by 15′ deep for a minimum amount of inside plating. This depth would bring a pressure on the bottom of $15 \times 62.5 = 937.5$ lbs. per square foot. This would require that the frames be very close together, and the bending on them would be so much that very heavy material would have to be used. With this consideration it seemed that it would be necessary to endeavor to make the design along some different lines, that would lighten the structure considerably. Thus we conceived the idea of giving the plating a curved form, so that the frames would resist deformation by tension. In other words, the plates could be given a curved form or permanent bulge, thus (see cut below), and for example let us assume



a $\frac{1}{4}''$ plate will be used and a span of 8′ between beams. Taking a portion 1′ wide we have a load of 937.5 x 8=7,500 lbs. on the portion of plate 8′ x 1′. Moment M=$\frac{1}{8}$ x 7,500 x 8=7,500 lbs., but the $\frac{1}{4}''$ plate is good in tension for about 15,000 x 12 x $\frac{1}{4}$ x .60=27,000 lbs. Thus "a"=7,500—27,000=.278′=3.33″. However, considering the fact that the plate is liable to deteriorate, it would seem better to make the offset not less than 4″.

In working out the details of the designs along this line it developed that the loops would have to run transversely, so that the tension of one plate would neutralize that of the other; or, we would have to put in horizontal girders at the side to take up the side pull of the plates. Running the loops transversly would make an exceedingly hard detail and cause expensive shop work at the side where the two loops come together and lead us to abandon the scheme.

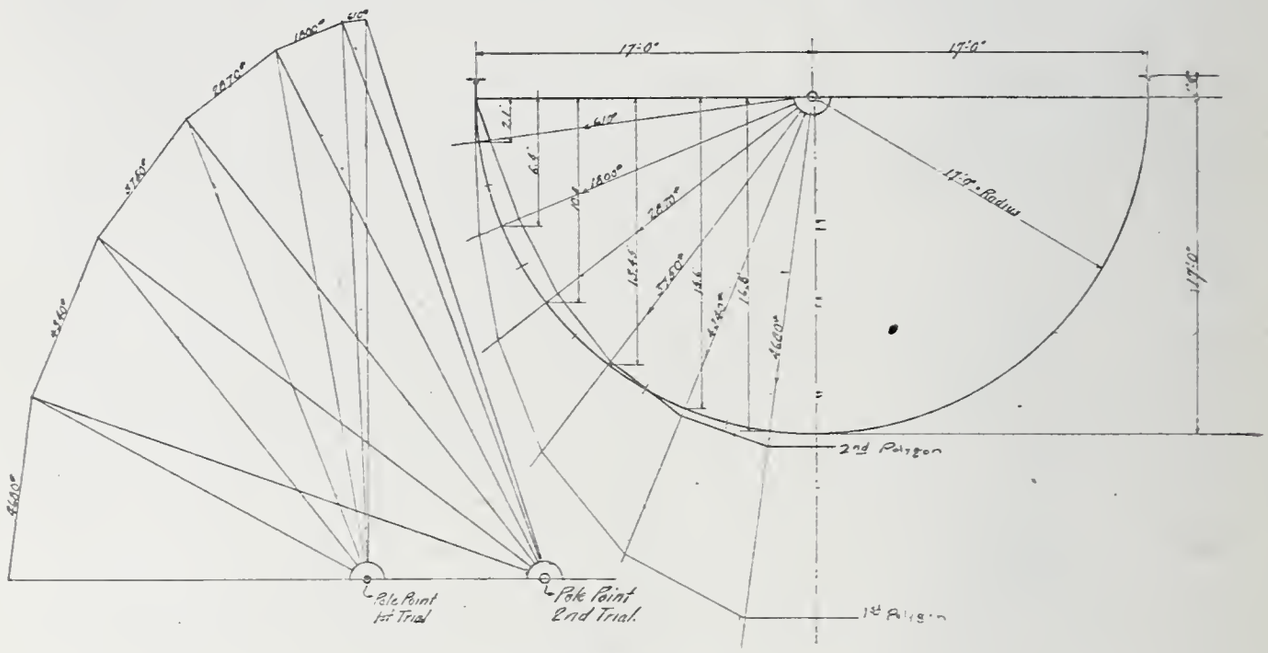
Right here I would like to suggest, however, that I do not feel entirely sure that it would have been necessary to take up all, or in fact any, of the side pull if the loops had been run the other way for I think that the looped plate would probably, under the pressure of the water, act like the web of a girder. If this had been the case I feel that we might have made a design along this line which would have been as satisfactory, and perhaps as economical, as any that could have been made. In the discussion I should be very much pleased to hear your views on this point.

In the following discussion I wish to consider two schemes of design, both of which are dependent on the pressure putting tension in the plates.

First, I wish to consider the treatment necessary to design the flume of one loop of plate similar to the Berquist type of coal bunker, with girders along the sides to support the loops. Second, I wish to consider a box form of flume with the lower corners looped something of the form shown on Sheet 10, Fig. 2.

In the first place we will consider the looped plate of the Berquist type. Those of you who have designed Berquist bunkers, know that for one that has no surcharge beyond what can be heaped on the top, that the side plates can be made straight for

a distance and then the arc of a circle put in for the bottom. To build a bin that will not deform, it is necessary to make the depth about .65 of the width, when the straight portion makes an angle of 30° to the vertical. As far as I know, there is no exact mathematical solution for the curve that the plate would take for a load due to the pressure of water, but there is a very simple solution, however, by means of the equilibrium polygon. That is assuming a chain is supported at its two ends and long enough so it will loop, you all know that if numerous forces were applied along the chain, it would take the same form as an equilibrium polygon. The converse of this method is often used in the design of stone arch bridges. This method was the one I used to determine the form that the plates would take in the loop, subjected to water pressure.

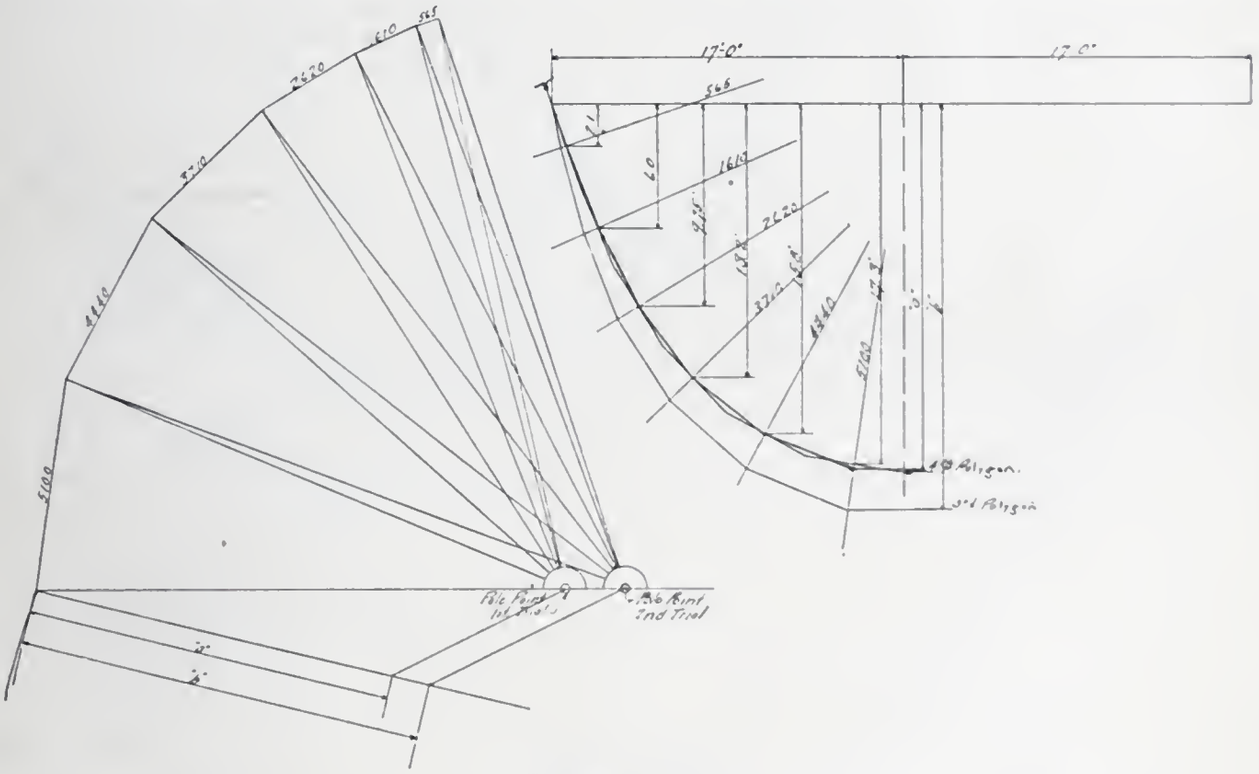


SHEET NO. 1.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 1st and 2nd Trial Polygons.

Though the graphical solutions are very simple, I wish in the following design to show how readily an equation can be solved by graphics and how few approximations it requires to arrive at a result. I started with the flume in the form of a semi-circle of 17′ radius, which gives an area of $17\frac{1}{2} \times 3.1416 \times \frac{1}{2} = 454$ sq. ft. As you will see by referring to sheet No. 1, I divided each quadrant into six parts. I then determined the pressure that would come on each 15° arc, assuming that it was

all concentrated at the central point. If the loop was a semi-circle, these forces would, of course, be radial, but increasing towards the bottom. I laid off these forces on a load line, as you see on sheet No. 1. You will note that I took the first trial pole so that the first ray was vertical and the last one horizontal. This would be the direction that the rays would have to take if the correct loop was a semi-circle, but after drawing the first equilibrium polygon, you can plainly see that this requires a much longer line and covers a much greater area than is required. Knowing that the length of arc of the semi-circle is practically correct for the required area, I took a second pole at a distance

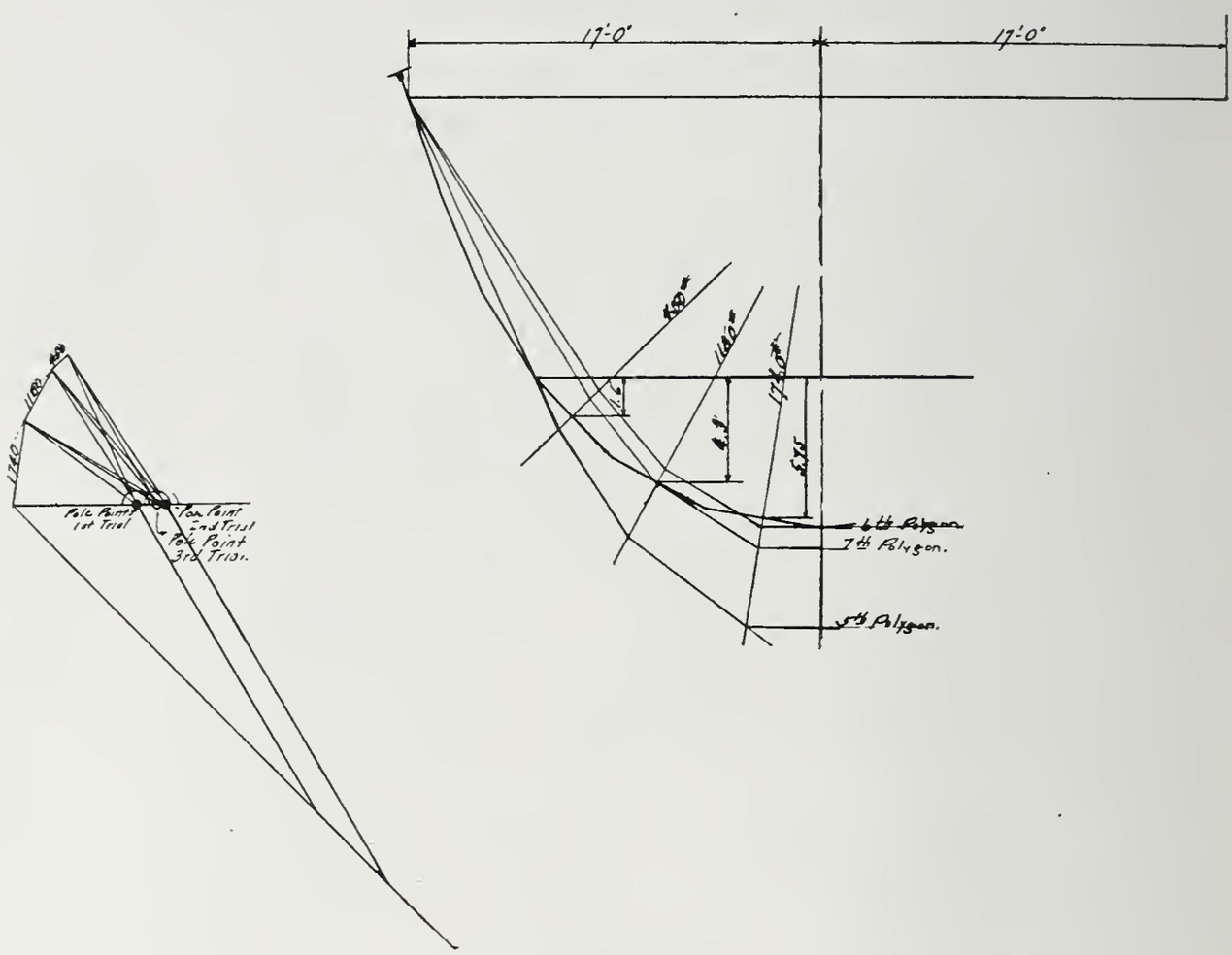


SHEET NO. 2.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 3rd and 4th Trial Polygons.

approximately in the inverse proportion to the ordinates of this polygon and the semi-circle. This gave a second polygon, whose length of arc is almost exactly the same as the semi-circle. You will note that I still made the last ray horizontal, as it will be necessary to have the polygon horizontal at the bottom. This second polygon gives the general shape of the curve that the plate will take, but only approximately, as for this shape the pressures used were in the direction and of the amounts used for the semi-

circle. Thus I took this second polygon and laid off the forces correctly, as shown on sheet No. 2, and repeated the same operation as before. You may notice I did not take the first trial pole distance the same as the second trial pole, on sheet No. 1, for I knew that this would be nearly, but not quite, correct, and so took one a little farther away so as not to mix up the lines too much. From this sheet you can see that the second polygon, drawn on sheet No. 1, was almost exactly correct.

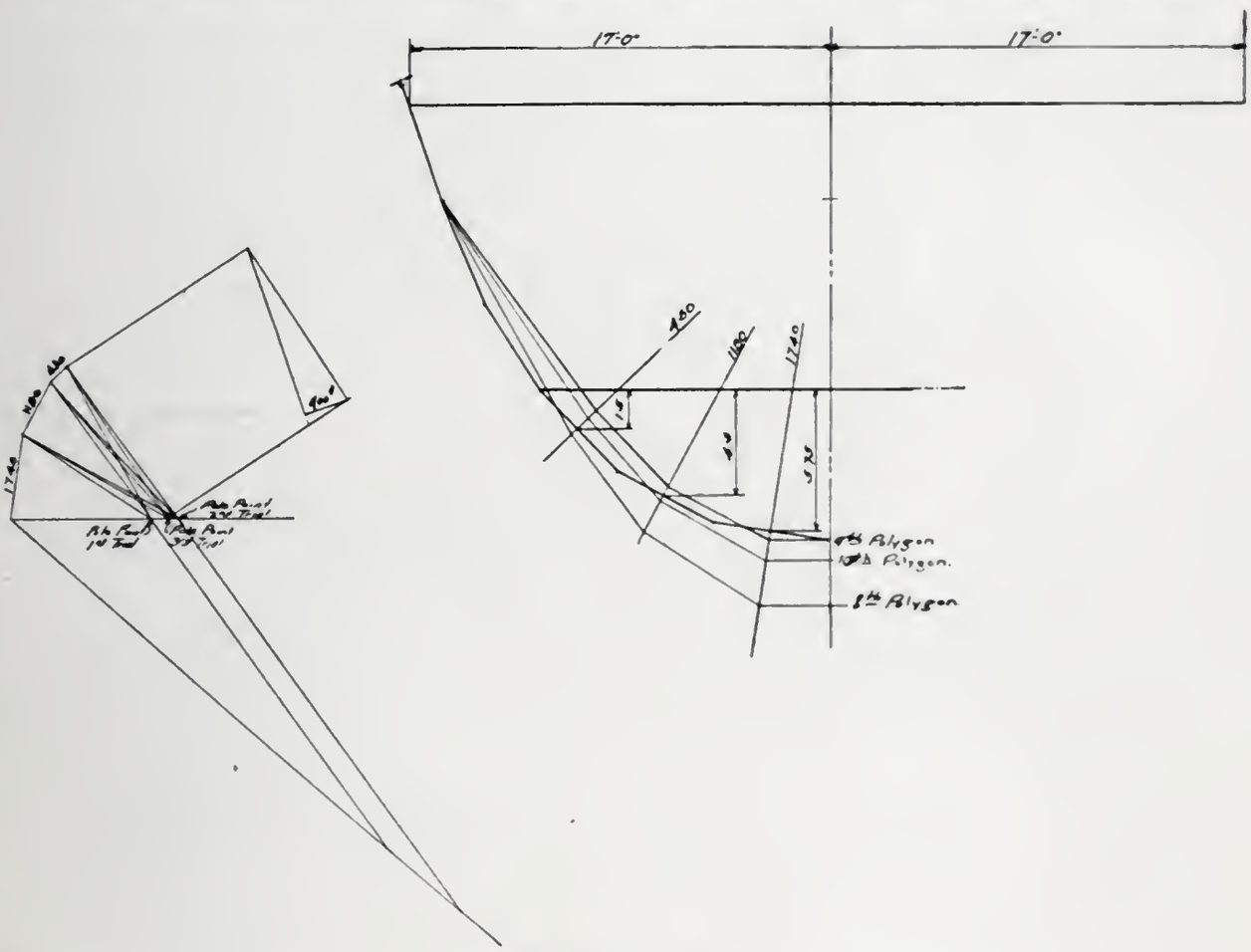


Sheet No. 3.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 5, 6 and 7 Trial Polygons.

The next point to be considered is the form that the curve would take if the flume were but partially filled with water. Thus I assumed that there was approximately 6 ft. of water in the bottom and drew the 5th, 6th, and 7th equilibrium polygons as shown on Sheet No. 3. You will note that the 6th polygon, which has the same depth as the 4th polygon, on sheet No. 2, shown approximately by the full

black line on sheet No. 3, differs from it materially in shape. By measuring the length of arc it is found to be quite a little shorter than polygon No. 4. The proportional lengths of the arcs were taken to determine a new pole distance for polygon No. 7, which should have the same length of arc as the semi-circle with which we started. Polygon No. 7, of course, is not the correct form for the curve, as the loads in amount and direction should



SHEET NO. 4.

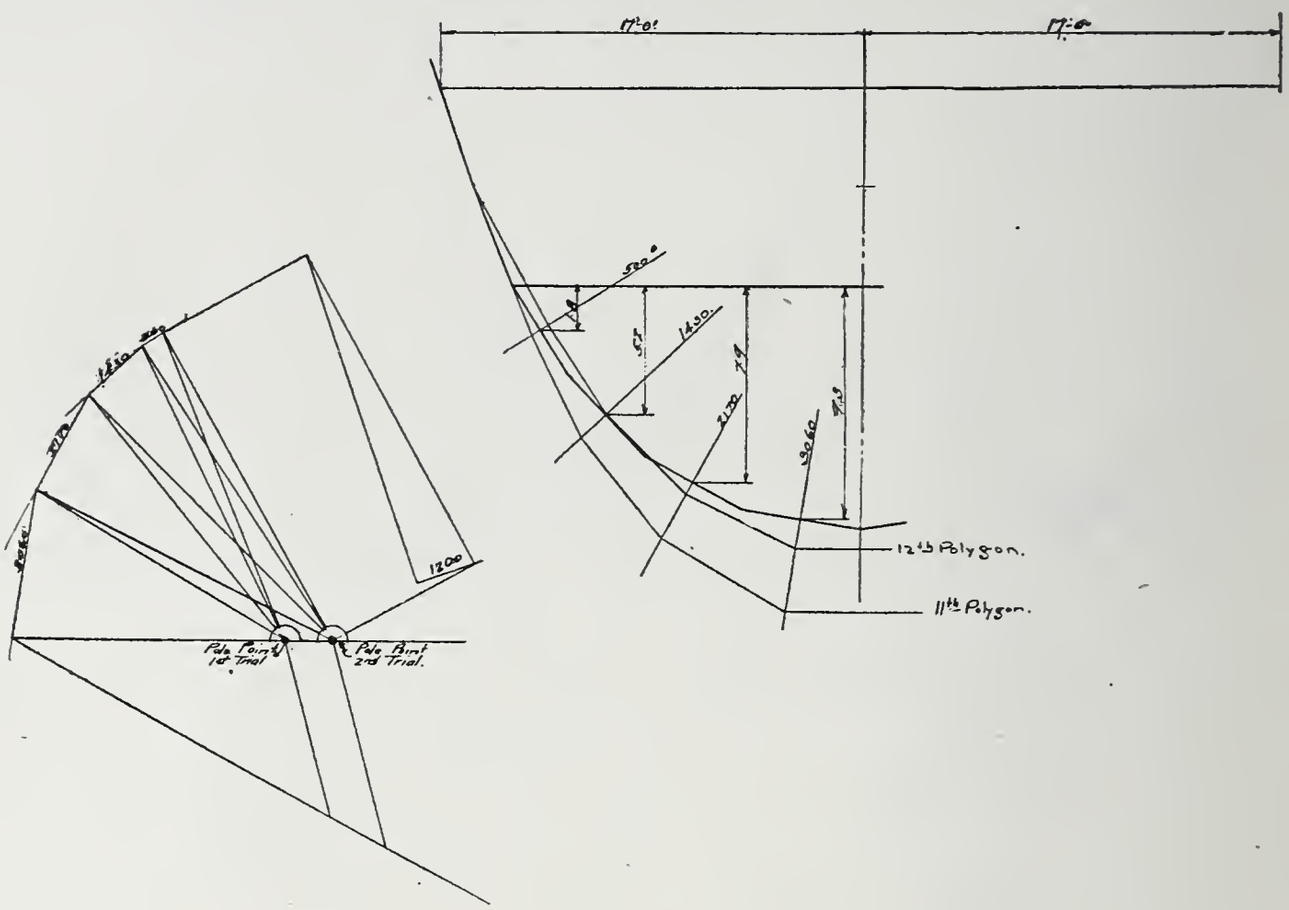
Design of Steel Flume of a Cross Section of about 450 sq. ft.
8, 9 and 10 Trial Polygons.

be corrected for the changed form of the curve, but it is approximate and goes to show that we will have to make provision for a twisting action on the girder. This will necessitate putting a channel on the lower flange of the side girder, so that that point would be fixed. Thus the form of the curve would be changed to something like that shown on sheet No. 4.

In drawing the three polygons shown on Sheet No. 4, you will note that I did not start from the same

point that I did for the first seven polygons, but assured that I would have a 5 ft. girder and that the lower flange would be 4 ft. from the water surface when the water was running at its maximum height.

As stated before, the bottom flange should be stiffened, so that this portion of the curve will not change its form, thus making it necessary to take this as a starting point.

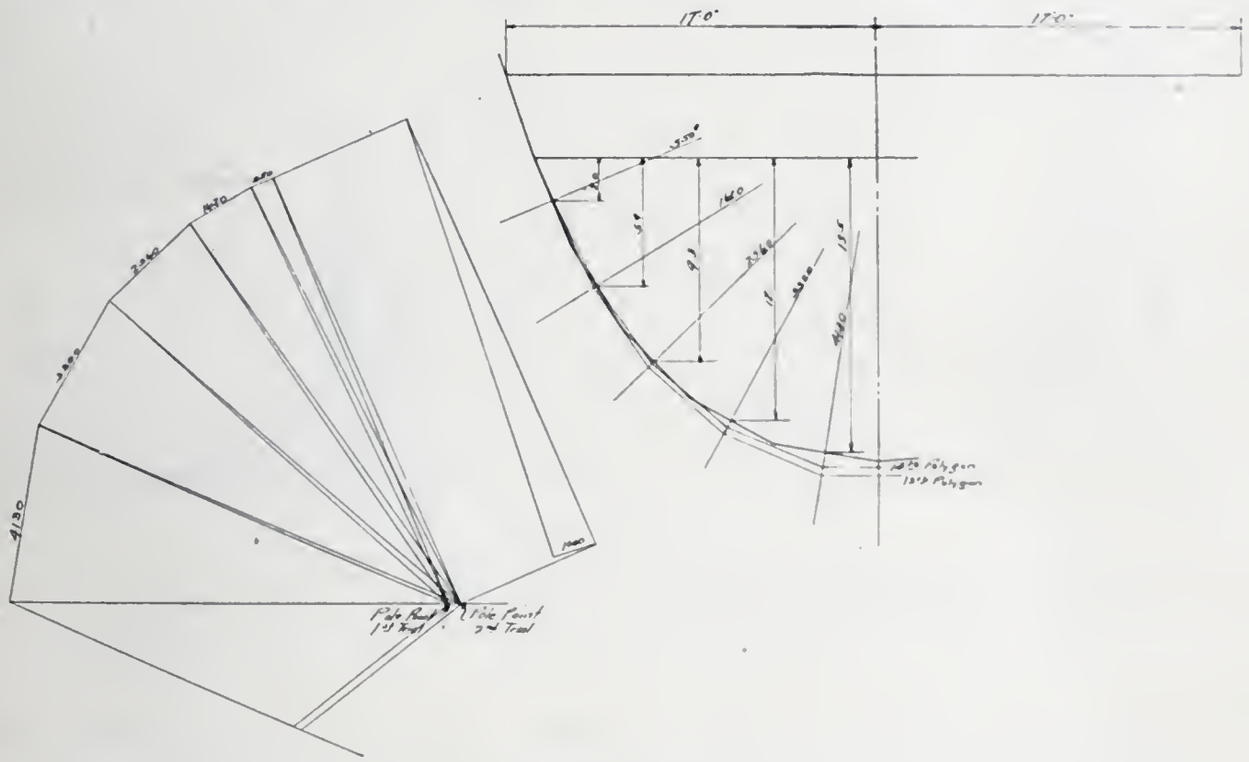


SHEET No. 5.
Design of Steel Flume of a Cross Section of about 450 sq. ft.
11th and 12th Trial Polygons.

You can plainly see from polygon 10, on sheet No. 4, that the form of the curve will change quite a little from what it would be in case the flume was full of water. It may suggest itself to some of you that this change in form would open the seams and cause leaking, but Mr. Donovan, an engineer who has had quite a large amount of experience in water-tight work on ships and tanks, assures me that we would experience no trouble from this. You might ask why then I stiffened up the lower flange of the side girders, but this was done as the ends of the girders would

be riveted to the columns and could not change form, but the center portion of the girder would take the new form, and this would cause the plates to buckle instead of change in a smooth curve throughout their length, which would be liable to open the joints.

In order to design the structure it is necessary to know the amount of the component normal to the web of the girder, so that the channel can be made strong enough to take this. To find this amount you will see that on sheet No. 4, polygon 10, that the pull on the girder from the plate is shown in amount and



Sheet No. 6.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 13th and 14th Trial Polygons.

direction by the first ray of the force diagram. Resolving this into its two components, one parallel and the other at right angles to the web, we have the amount required to be 900 lbs. per lineal foot. However, this is for a 6 foot depth of water, but we have no way of knowing that this would be a maximum.

Thus I drew polygons for two other depths, as shown on sheet 5 and 6, and found that for the depth shown on sheet No. 5, we have a maximum for the three assumptions. You will also note that on sheet No. 4 the depth was smaller than on sheet

No. 5, and on sheet No. 6 it was greater and still the side pull was less in each case. Thus it is evident that the depth shown on sheet No. 5 is practically a maximum.

The mere proportioning of the different members does not present many problems of interest. There must, of course, be a girder designed along the top at each side. To get the load per lineal foot of this girder you simply have to scale the length of

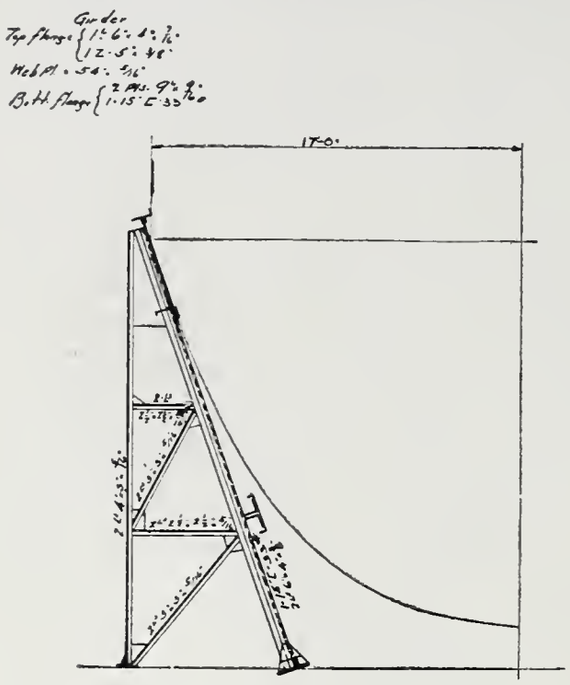


Fig. 1.

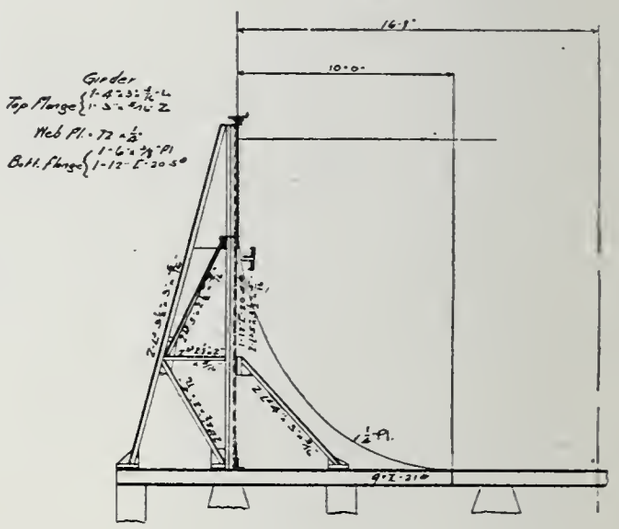


Fig. 2.

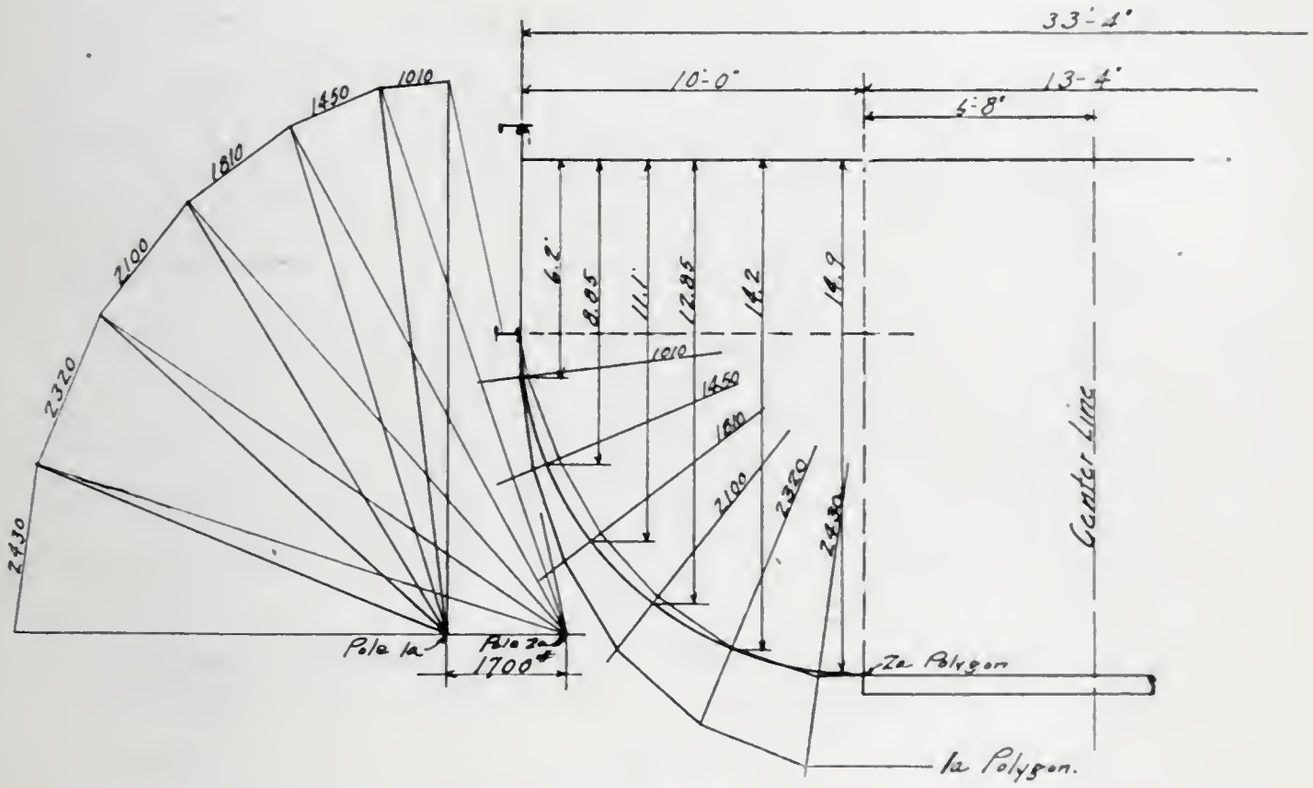
SHEET NO. 10.

Design of the Flume of a Cross Section of about 450 sq. ft. 2 Cross Sections.

the first ray from the second trial pole. This we find to be 14,500 lbs. per lineal foot as measured from the 2nd trial pole on sheet No. 2. Assuming the columns to be 16′ centers, we would find the load on each girder is 14,500 x 16=232,000 lbs. The top flange of the girder was made up of one zee and one angle as it would have a little more lateral stiffness than two angles. The A frames for the support of the girders were designed in the usual way. We made the direction of the main portion of the column the same as the transverse direction of the web of the girder. You remember, however, that when partially full, this is not the direction of the force, and that the side pull, which for a maximum is about 1,200 lbs. per lineal foot, would amount to 1,200 x 16=19,200 lbs. per bay, which would bring

an uplift on the outer legs of the A frame amounting to $\frac{19100 \times 17.5}{8} = 42{,}000$.

This would have to be taken up by anchor bolts which would require quite a little masonry where it would have but little other use, and is one of the main objections in my mind to this design. We could, of course, use a strut from side to side, as is done in the case of a coal bunker, but the ice might be liable to injure this.



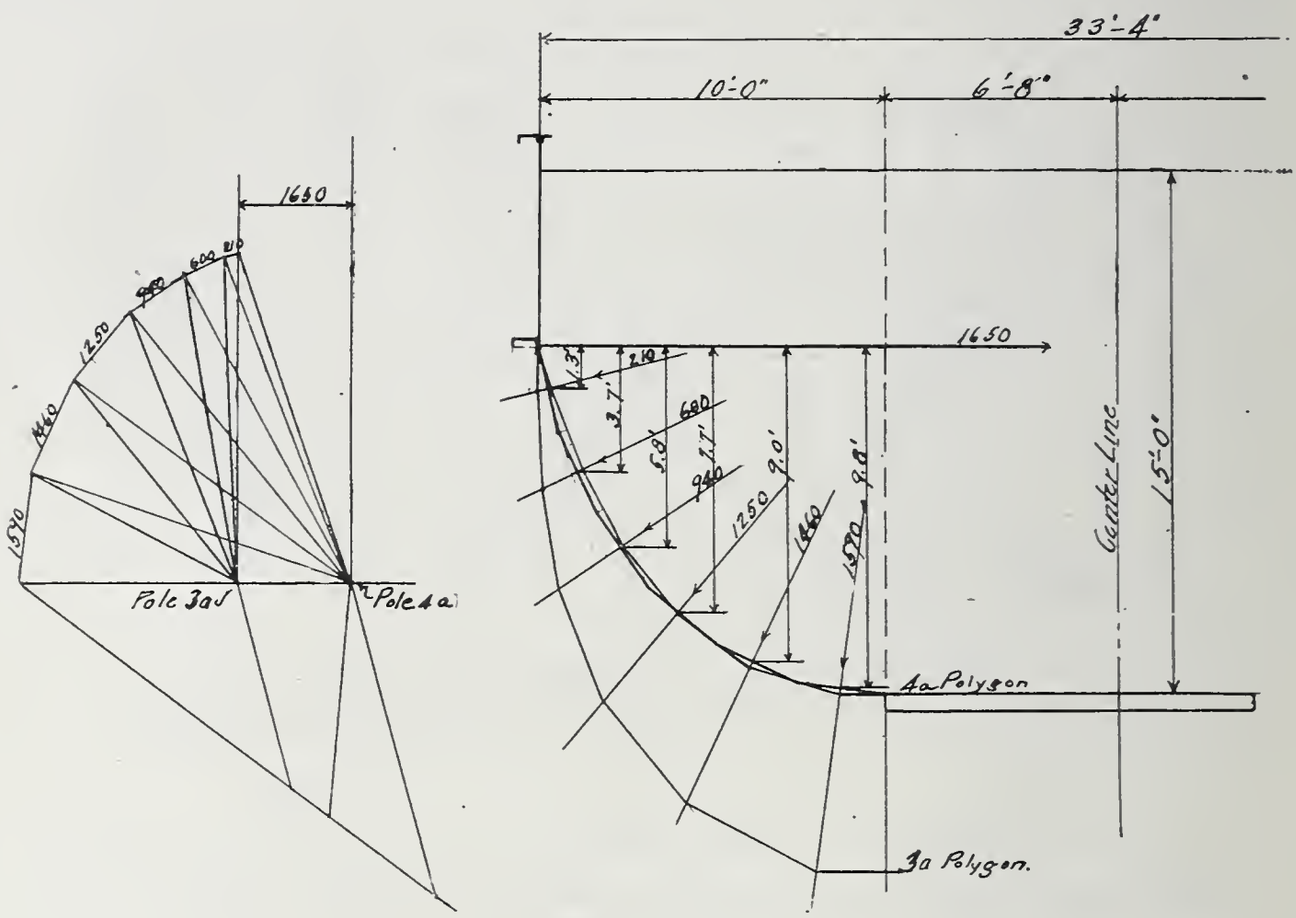
SHEET NO. 7.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 1a and 2a Polygons.

In the design shown to the right, on sheet No. 10, you see that beams running transversely to the flume are used to support the central flat portion and then a curved loop, which is supported at the sides by a vertical girder. I made the depth of the water 15 feet over the flat portion, and started with the assumption that the curved portion would be the quadrant of a circle 10 feet radius.

I then followed the same course that I did in the former design and found the form of the equilibrium polygon as shown on sheet No. 7. You will note that

the last ray of polygon 1a is horizontal and that the length of the arc is shorter than it would be for the semi-circle. I then measured the area of the curved portion of the cross-section and found that the total width of the flume must be 33 feet 4 inches in order to give a total area of 450 square feet. You will see that the curve does not differ very materially from the semi-circle and would vary but little if corrected for the slight change in amount and direction of the



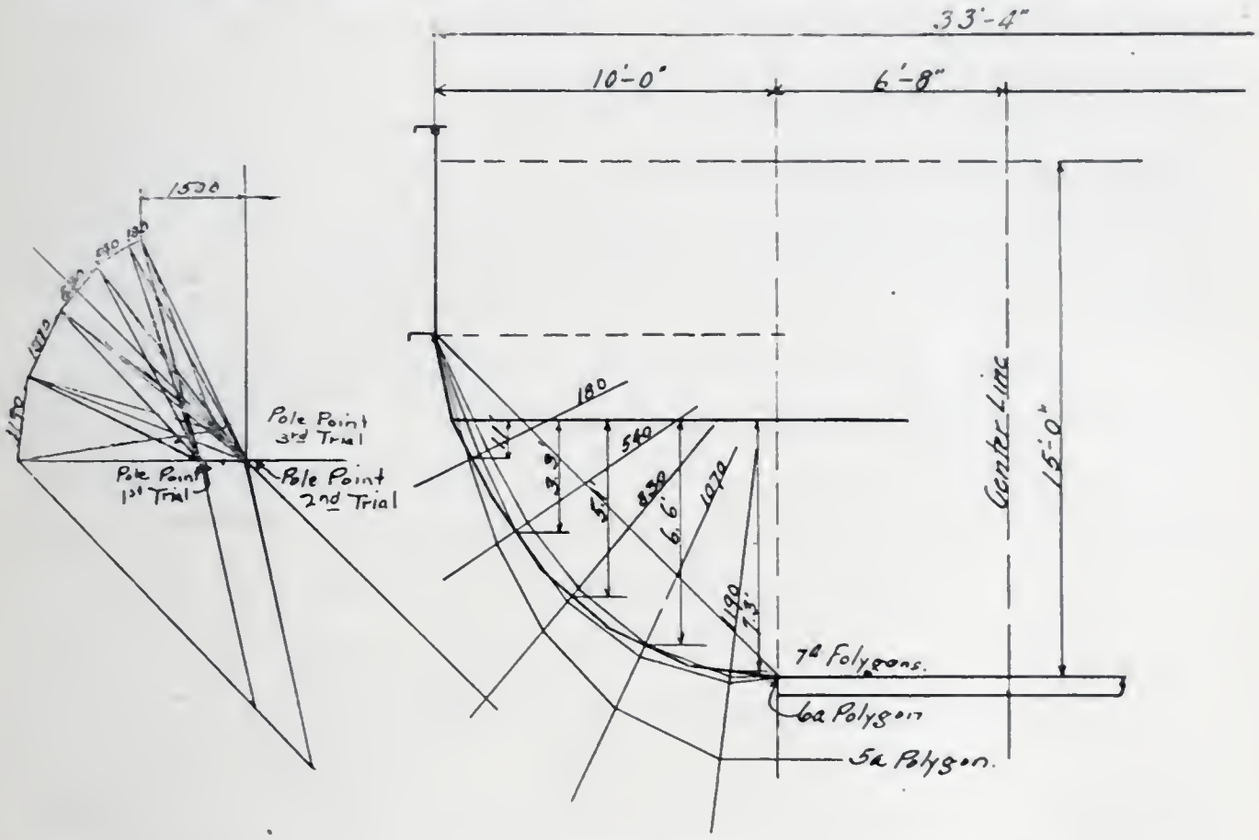
SHEET No. 8.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 3a and 4a Polygons.

forces from that of the semi-circle. The horizontal projection of the first ray of the force diagram is seen to be 1,700 pounds, which will be the side pull of the plate at the bottom flange of the girder, and will have to be taken up by a channel turned with the web horizontal. However, part of this 1,700 pounds will be neutralized by the outward pressure of the water on the side of the girder at the top. This amounts to 520 pounds and leaves a net inward force of 1,700—520=1,180 pounds per

lineal foot. We, however, have not determined whether this force will be a maximum when the flume is full.

On sheet No. 8 the polygons were drawn, assuming that the water level was 10 feet deep or just even with the bottom flange of the girder. You will see that the horizontal projec-



SHEET NO. 9.

Design of Steel Flume of a Cross Section of about 450 sq. ft. 5a and 6a Trial Polygons.

tion of the first ray is 1,650, which gives the horizontal inward pull from the plates. There is no pressure, in this case, against the girder, so this is the net pressure which must be taken by the channel for this depth of water.

By referring to sheet No. 9 you will see that I made another trial with a still smaller depth of water, and in this case the inward pressure was less than before; hence, 1,650 is about the maximum.

You will note that in all the diagrams that I have shown the pole has been so taken that the last ray has been horizontal. However, the second polygon on this sheet can be seen is shorter than the polygon on sheet No. 8. This is not the correct polygon, as, of course, the length of the arc is a

fixed quantity. Thus it may be seen that the last ray cannot be horizontal, and, therefore, the pole point is not on the horizontal line from the lower end of the load line. We, however, know one point which can be used as a pole and cause the equilibrium polygon to pass through the two points where we have located the ends of the curve. If through this pole a line be drawn, parallel to the lines connecting the ends of the curve, this line will be the locus of all the pole points which will terminate at the extremities of the curve. This is illustrated on sheet No. 9, and when the locus line of the poles is known it is very easy to find the pole point for a polygon of any given length.

In the flat portion of the flume I assumed the beams would be spaced 2-foot centers, which would be a clear span for the plate of about 1.6 feet. Thus on a portion 1 foot wide we would have a load of 937.5x1.6=1,500 pounds.

$$M=\frac{1500 \times 1.6}{8}=300$$

$$300\div 27000=.011'=\text{deflection.}$$
$$=.132''$$

Thus you see that the offset required, in order not to exceed the safe tensile strength of the $\frac{1}{4}''$ plate is only slightly more than $\frac{1}{8}''$.

The dimensioning of the members for the various parts does not possess any special features, except you will note that it was necessary to put in a brace on the inside of the A frame, as the beams which will project out were not strong enough to withstand the overturning.

In comparing the two designs there would be comparatively little difference in the expense of the shop work. The plates will not have to be curved in the shop, but in erecting the work they will readily draw into position. This has been done in the case of coal bunkers, when the radius was smaller than in this case. It will not be necessary to rivet the plates in the second design to the supporting floor beams, and the transverse laps should be so arranged to come between the beams.

I thank you very much for your kind attention and I am verry sorry that I did not have the drawings here, which would have illustrated very much better what I had to say than I could do by sketching on the board.

DISCUSSION.

PRESIDENT—The subject is now open for discussion.

MR. WHITED—I would ask if it would be practicable to place struts across the top in such a manner as to clear any obstruction that might be met with and that would resist the initial component more economically than those posts would. It is quite possible to construct such struts and still have plenty of room.

MR. BALCOM—A strut could have been designed to extend across the top high enough up to clear the ice, but even if this were used we could not dispense with the back legs, as these are necessary to resist the wind pressure on the side. Whether it would be cheaper to take up this side pull by means of a strut, or anchor bolts and additional concrete, would depend largely upon the condition of the ground on which the foundations were built, and the cost of the concrete.

These points I did not go into very fully, as I was not particularly in favor of this design, and my chief object in showing it was that it illustrated better than any other the graphical method of determining the form that loop plates would take under various pressures.

MR. KNOWLES—I am interested to know how much that flume would cost per foot.

MR. BALCOM—The weight of it is about 1200 lbs. per foot. The cost would, of course, vary with the location and accessibility for erection.

MR. KNOWLES—$60 probably per foot? I presume it must be for a gravity flow. Was there any particular trouble from rock excavation or anything of the sort?

MR. BALCOM—It was along a creek bed; I suppose there was rock for the foundations.

MR. KNOWLES—Why was not the usual concrete conduit used? That would avoid the foundation piece and it is general-

ly recognized as the cheapest type to carry water. I inferred from the discussion that this last type shown was the one adopted and built.

MR. BALCOM—I believe the last type is the better; neither of these types were built.

A MEMBER—The design giving the smoother surface gives a much better flow of water and if it is not always to flow full, that type of conduit which gives a narrow channel at the bottom would also give us a proportionately greater flow as the depth would be greater for a given discharge.

MR. BALCOM—My understanding of the matter as to whether it would flow full of water or not, was that under all ordinary conditions, it would be full of water similar to a race-way and that the small amount of friction on the bottom would be of almost no consequence whatever. Of course for a fifteen foot depth of water, the friction on the bottom would not impede the flow of water much. In all these cases the smaller depth of water had, of course, to be figured for, not so much that this would be of normal condition, but that when it was being emptied, the loop plates would go through the changes in form.

MR. STUCKI—Would it not be more economical to form a strut between the two posts underneath the tank instead of having those anchors, as they are certainly very expensive? In regard to sketch, Sheet No. 10, you will have a very dangerous point just at the junction of the thin plates with the bottom girders, because you have two points of support; one is the top girder, and the other is the floor beam, which do not always work in conjunction with each other, causing relative motion. Another reason for such a motion is due to a difference in the head of the water, and therefore, there seems to exist a tendency to rupture those plates right at the junction with the floor beams.

MR. BALCOM—I think your point, that plates would be liable to rupture if subjected to a constant bending motion, is no doubt true, especially if there was a considerable amount of motion, but in these designs the plates moved but very little, and the change in depth of water would be so infrequent that I do not think this change of motion would occur often enough to do any injury.

MR. KNOWLES—Regarding the question of the curved plates. It may seem strange, but I have no doubt that the conduit will carry more water if made closed over these hollows. Some designs I know of, wooden flumes about 12 feet across and built with large timbers inside, were repaired by planking inside the timbers, not outside. More water was carried than before due to the smooth surface. There is no doubt, therefore, the conduit will carry very much more water if built flush inside than outside of the projections.

As to the concrete conduits: two concrete conduits about 15 feet in diameter will carry as much water as that one shown, and would not cost any more.

MR. HAWLEY—The point Mr. Stucki made regarding the damage to the plates by bending is well taken. I had a little experience in that line some years ago, in the case of a standpipe 15 feet in diameter and 132 feet high. The water was pumped into the standpipe several times during the day and the pumps shut down until the water had dropped from near the top of the standpipe to perhaps 50 feet. I was called one night and informed that the standpipe had bursted. Upon examining it, I found the water spurting out all around from under the bottom of the standpipe. The next morning after draining and getting into it, I found that a plate immediately over the caulking edge of a lower plate had split for a distance of from 2½ to 3 feet and that the plate had rusted nearly through from both sides for the length of five or six feet along that same caulking edge. The standpipe had been erected without the inspection of an engineer, had been lowered on to the rubble masonry foundation without the bed of mortar or sand that is usually placed under such a structure. The result was that the rivet heads on the bottom rested on the stone of the foundation. As the head of the water increased or decreased, the plates would bend and that action has been taking place for about ten years, until this plate had cracked, both above and along that caulking edge, and finally broke off entirely. Others showed the same action. It was a small standpipe and exposed to very heavy and frequent winds and we had no way of guying it properly to make it safe when empty, and the question arose as to what we could do. I mixed

up some salammoniac, flowers of sulphur and iron filings, and put it over the crack and after giving it a few hours to set, it leaked very little at first and in the course of four or five hours became tight and remained so for some weeks until we could make permanent repairs.

I should be very much afraid that a structure of the kind which has been described, which allows any bending of the plates, especially over an I beam or any other solid portion of it, would not be satisfactory.

MR. WHITED—That is a matter that is familiar to all boiler makers. That wherever a plate is subjected to localized bending strains, it corrodes more rapidly than elsewhere.

MR. HAWLEY—This is particularly true of a structure holding water, because there will be the action of the water on one side and the alternate action of the moisture of condensation and of air on the other.

PRESIDENT—Any further discussion? If not, a motion to adjourn is in order.

Motion to adjourn carried.

C. W. RIDINGER,
Secretary.

FORGING MACHINERY.*

BY JAS. H. BAKER.

You perhaps remember the picture of the blacksmith before King Solomon after the Temple was built. To him was accorded the highest honor, because none of the artificers could have performed their tasks, but for his craft.

Each man's profession in its application may seem to have the greatest number of variations, but on looking over the field of articles made by forging machinery, one can only touch this question in a broad way within the limits of this paper.

It seems to me that I can hardly expect to say much that is new, and the most I can hope to do, is to put the main points of the matter into a more or less related form.

Forging machinery consists generally of hammers, forging rolls and presses. We leave out of this paper cold drawing, as it occupies an intermediate field between forging and machine work, and consider only hot work. From a stone in the hand of a man to the 125-ton hammer has been a long road. In power hammers, we have trip hammers driven by a kind of cam, helve hammers and various types of upright hammers driven by belts, through excentrics, etc., steam hammers of both the forge and drop variety, hammer heads raised by a crank lift or windlass, or by a board working between friction rolls, and the hammer head allowed to drop on the work. These two last named are strictly drop hammers. The steam drop hammer is much like them, except that in it the falling of the head is generally accelerated by live steam. I do not go into the field of air hammers which are taking the place of hand hammers in many kinds of cold work. There are, however, several kinds of air hammers for forging, some on the principle of the steam hammer and some with individual air compressors forming part of the machine.

*Read before the Mechanical Section November 1st, 1900.

Drop hammers, generally speaking, as used for forgings, are those suited for using dies having a matrix, usually formed with part of the matrix in an upper, and the other part in a lower die, the work being compressed into this matrix by the blows of the hammer, and the surplus metal trimmed off.

In drop hammers where strokes of uniform force are required, the crank-lift or board-lift is desirable. These are practical up to a reasonable weight of head, and for one stroke work, are well adapted. But for work requiring strokes of varying force, the steam drop hammer I think superior. The difference between steam drop and steam forge hammers is in the valves and arrangements of the guides. Belt transmission of power from an economical engine is cheaper than power derived direct from a steam cylinder on a hammer.

In a steam forge hammer having a head weighing 125 tons, falling a good distance with steam, in a correspondingly large cylinder driving it, we have something very powerful. Steam forge hammers have a wide field of use that I need not describe here. But in a general way, they are used much as a blacksmith works, the hammer doing the striking instead of the human helper.

The trip hammer formerly was much used for forging hoe blades, fork tines, etc., because of its simplicity and hardihood, and with various forms of driving cams, this style of hammer is useful in chain welding, bolt heading and innumerable other kinds of machine forging.

For light work which can be handled rapidly, and which needs to be turned as it is being forged or welded, the belt driven hammer is preferable. This class of hammers reached and passed their limit at car axles.

While the hammer will always be largely used, it is being superseded on many articles by the forging press and forging rolls. This change in favor of the press is clearly exemplified in the manufacture of armor plate and some other heavy forgings. It may be risky to say that anything mechanical has reached its limit in size, but I believe that the 125-ton steam hammer reached and passed it. The forging press in its lighter forms is

used for making pick eyes, forging picks, hand hammers, chisels, sledges, etc.

As to the limit in drop hammers, we now have steam drops with heads as large as five tons, and I am inclined to think that this is about their limit. The shock in drop hammer work is very great and repairs correspondingly so, and an additional source of trouble is that a good deal of work often comes at one side of the vertical line of the piston rod, and this is hard on piston rods and guides. I think the forging press in connection with the drop hammer will tend to remove this difficulty.

Forging rolls are now used for making many articles in whole or in part, formerly made on hammers, such as fork tines, brake shoe keys, ends of springs, horse nails, harrow discs, sucker rod joint-straps, tapering plow-beams, etc., etc. For instance, here is a piece of work in which a bar of 1 x $\frac{1}{2}$", $7\frac{1}{2}$" of which has been drawn to a length of 16" at a single pass in eccentric rolls, most of its cross section being reduced to $\frac{1}{8}$" x $1\frac{5}{8}$", the actual time of contact being less than $\frac{1}{2}$ second. The same work under a hammer would, as you can easily judge, have taken many, many times as long.

But quality of product is another quite important factor, especially in heavy work, therefore the question of hammer versus press must be decided accordingly. The press forging method, so far as it is applicable to heavy work has decidedly the lead. This is so well known that it needs only to be mentioned. Press and roll forging very often have the advantage of a great saving in die cost, as cast metal can be used for dies.

Another largely used form of machine is that of the bolt heading type. Generally, there is a gripping device placed at an angle, usually a right angle to the line of travel of the heading tool in these machines. In the larger sizes they are often called up-setting machines, forging machines, etc. They are driven by pneumatic or hydraulic means, by gearing actuated by electric motors or by transmission of power through belts. And here again, each form is most fitly adapted to certain kinds of work. One would not think of using a hydraulic machine to head one-quarter inch bolts, while nothing but hydraulic means would be thought of for drawing a twelve-inch tube. And in

certain cases the question of rapid versus slow motion would be the deciding factor.

In bending machines the foregoing description of forging machines of the bolt heading type will hold good. Where the stroke of the traveling die has to be of uniform length, if possible, the geared machine should be used. On the other hand, if the work is of such nature as to have an uneven amount of metal under the die at its finish, it is better to use pneumatic or hydraulic means. For instance, you might make certain kinds of bends in bars of varying thickness, in a pair of dies without changing the set of the dies by using pneumatic means. Again, you can have a very long stroke pneumatic machine and yet make quite short strokes when needed, and this is often quite economical.

There are forgings which can be most economically made by a combination of methods. Here is a shovel socket that was produced economically and nicely by a combination of three methods. The flat end was made in a drop hammer, the short tube was made in forging rolls that drew the walls of the tube at one end to less than one-half their thickness at the other end, and at the same time welded the tube and then a rapidly striking hammer was used to weld the heavy end of the tube to the drop forged part.

Proper heating is an important factor in forging and should perhaps have some mention here. To illustrate, if you wish to make an upset of 2 inches in thickness by 4 inches in length, on the end of a bar one and one-half inches thick, the back part of the metal should be much the hottest, or the front part of the holding die will fill first, and the back part will not fill. Again, improper heating will allow oxidation and so make trouble in rough work, bad welding, etc. We have heard a good deal about some kinds of fuel making iron softer and easier to work, etc. Now I do not believe there is anything of this in the fuel *per se* and yet there can be no doubt as to some heating being better than others. This is due to unsuitable burning devices. It all seems to be a question of how far the perfect mixing of oxygen and carbon can be accomplished, and at the same time be advantageously applied. Repeated experiments in welding

chain links showed on an average, that one hundred pounds of links heated in the blaze of coke lost seven-eighths of one per cent. in weight, while the loss when heated in natural gas was two and one-quarter per cent. But this only showed that free oxygen found its way to the metal more freely in the gas heating. I need only mention the fact of enclosing bright articles in a sealed box and heating them by applying the heat to the outside of the enclosure as an example of what can be done without scaling when oxygen is practically kept out of reach. Producer gas for light work is used, but the matter has not been carried far enough in my opinion to determine its value. Petroleum and its products are used, but it takes rather elaborate devices to get good results.

In welding, please distinguish between electric welding which in many cases consists in fusing or melting the surfaces together and welding proper, as generally understood. In electric welding, the metal is often brought almost to the ingot condition, and when the article is in such forms as to allow of little or no subsequent work on it, it is left in a more or less honeycombed condition. By welding proper, I mean heating the metal to a degree below the melting point, and in cases of particular work much below it, freeing the surfaces from oxide, dirt, etc., and hammering or pressing these clean surfaces together until the weld is made. This leaves the condition of the metal nearly as good as before. The press is not well adapted to making lap welds, the slow motion causing a comparatively long contact of the dies, thus cooling the thin part of the laps before the weld can be completed. Iron or steel need not be very hot to weld, the extra heat usually given serving the purpose of freeing the surfaces from oxide and keeping them free until the weld is made. The higher heat also softens the metal, making it easier to forge to size while welding, as in many cases it is difficult to get at the ends of laps until the press has been brought about to size. In soft steel and iron we generally bring them to a bright sparkling heat, which melts the oxide. In high carbon steel this high heat would not be allowable, and therefore a chemical agent is used

such as borax, etc., to reduce the oxide to a fluid condition at a comparatively low heat.

Electric heating and welding has a field peculiarly its own, where nothing can equal it, such as uniting forms which do not admit of work after welding, joining light work, uniting the ends of pieces of pipe, and welding where an electric current can be carried to the work while in place, which would be an impossibility with a forge fire. On the other hand, in large cross sections, in electric welding as usually practiced, you would heat the central portions of the cross section more than you would the edges, owing to radiation, and therefore by the time you had the edges hot enough, the central portion would be too hot. Thermit welding, so far as I can see, has some of the same limitations as electric. In fact welding might be generally divided into two classes, one in which physical work is the principal agent, and the other in which it is absent or only incidental.

Some years ago, I saw a very interesting thing in automatically welding 12″ pipe, the pipe being spirally bent, the edges heated and welded in a continuous process from start to finish. But it proved to be troublesome and did not stop for a defective spot in the weld, and has, I believe, been discontinued. In this work water gas was used after scrubbing out the sulphur, and the fuel gas used under the boilers.

Automatic working of metal has been carried to a high degree of efficiency in cold work, but in hot work it has not advanced much, the reason mostly being in the fact that one of the fundamentals in automatic work, is that the product of each separate operation must be uniform in order that feeding or changing devices may transfer the work to the next form, or die. The difficulty is, that the heating may be irregular, the loss by scaling greater or less, and therefore the action of a given operation will not produce a uniform product. But in articles which can be grasped at one end and worked from this hold, automatic work is practical in hot metal. Hence, we see it done in the manufacture of rivets, spikes, horse nails, etc.

One of the most important questions is how to group, or arrange machines. In a shop where a variety of articles are made,

it is next to impossible to do this so effectually that the sequence of operations will not sometimes be interfered with. I can only say, that machines should be grouped so that the work may pass directly from one machine to the next, rather than have each class of machines set by itself, which would mean all the hammers at one point, all the presses at another, etc.

Now let me describe the first power forge I ever saw. Picture to yourself a narrow valley between mountains where the sun shines only a small part of the day, a road leading to it so rough that two horses could hardly haul a ton of iron, a small stream of water carried along the hill side until it has a fall of, say fifteen feet, then falling into a vertical box, this box joined at its lower end to another box lying horizontally, having an escape at its opposite end for the water on its lower side, and on its top side a hollow log for a pipe and you have the blowing device, by which the pig iron was melted in an open hearth forge fed with charcoal. Then a dam, a water wheel made of wood, its shaft extending into a log building with a clap board roof, a trip hammer run by projections set in this shaft to drive the hammer, and you have a forge that made about one-half ton of bar iron in a day. From the foregoing it will be seen we have a great variety of forging machinery, but we shall always have use for knowledge, experience, industry and hard common-sense, and for the welfare, development and happiness of humanity, I am glad of it.

DISCUSSION.

MR. MCMULLIN—Mr. Baker, were you not mistaken in saying that they have no uniform heat in electric welding? Does not a hot metal offer a greater resistance than a colder one? So that the moment a part of the metal becomes hotter, the increased resistance of that part reduces the current flowing through it, and so equalizes the heat?

MR. BAKER—My one reason for saying that was that an electrical authority, that I thought was a pretty good one, says so, and the other reason was from the fact of breaks I have seen.

MR. LYNCH—As to electric welding, I would state that I have seen some most excellent welding in the form of bolts,

where the head has been welded onto the shank of the bolt. I have tested many of them by passing the bolt through a plate on the top of the testing machine and clasping the end of the bolt with the lower jaws of the machine, and thus pull the bolt. The bolts invariably broke near the weld, but never in the weld. It is evident that the steel near the weld had been annealed and thereby softened, producing a weak place.

In some of the bolts referred to, a brass head was welded to a cold rolled steel shank, in which case the annealing results on the steel shank were similar to those when the steel head was used.

It is very evident that electric welding has come to a much better basis than it had some fifteen years ago, because progress in electricity has been very great in those fifteen years.

Mr. Baker stated in his paper that there was no particular difference about the kind of coal used. I would like to ask if coal having a great deal of sulphur does not affect the welding quite detrimentally?

I would like to ask Mr. Baker, also, in reference to the dies in the forging operations, whether or not they should be chilled or made in plain cast iron molds?

I would like to call attention to another sort of welding that has not been touched upon to-night, that of brass pipe welding. I have had occasion to take care of some work where we had coils to weld, say three-quarter-inch brass pipe. In accomplishing this, we found it necessary to cut the pipe off on a chamfer, fit the edges together very neatly and make the joints with silver solder. In our experiments we found, that by using the brazing solder of the ordinary kind, which is practically yellow brass cuttings, it burns the thin part of the tube before it affects the weld, while in the silver solder the weld is affected, and a good substantial joint is made without injuring the thin edge of the brass pipe.

MR. BAKER—In reference to the gentleman's two points: The question he mentioned last, I have never had any experience with worth talking about. Of course, we used to braze, but I believe we never called them welds. We called it brazing, no matter how we put them together. In the cast iron dies mat-

ter, there are a great many cast iron dies that don't need to be chilled. There are a great many others, of course, that ought to be chilled. But when chilled, a hard iron is needed; we find often that we can use malleable iron before it is annealed, what is usually known as white iron.

It has this advantage, that if you want to make chilled iron, you have to make a pattern, make a chill piece and all that sort of thing, while to get the white iron article, all you have to do is make a pattern and take your casting off it. I have seen very lasting punches in heavy work made of good charcoal iron without being chilled, and in common forging dies, we never think of chilling.

MR. MCMULLIN—Replying to Mr. Lynch's question about coal, I would say that sulphur in coal is detrimental to welding.

MR. R. A. MCDONALD—Before we drift away from the question of electric welding I would state a little experience I had. As to the theory of the heating, I would like to have an opinion from an electrician. My idea in that is simply that the pressure makes it that way. My experience was this: We were making quite a lot of specialties in the way of thin steel. In many cases the steel would break before it was annealed even. That was, of course, due to overheating. The question is whether they can overheat by electric current as readily as in the open fire or any other way of heating. Take any steel or iron; if they burn it, of course, it is a poor weld. The electric welding people may not be able to control that to the same nicety as you would in ordinary welding. I have seen many cases where we could re-roll this steel by annealing it and put it in better condition than in the original welded condition. In many cases it would break, but we would cold roll it and my opinion was that it was simply a case of carelessness on the part of the electric welders in not getting the heats uniform in all welds. In some cases we cold-rolled it as thin as .012 inches. Yet the steel held and we would have other cases that would break in the first rolling. Generally, though, it held all through. In alloy steel it worked the same way; the same difficulty was experienced there, though it would be in some other cases poor welding. While we are on this subject, I

would like to ask Mr. Baker in his judgment, what is really the best method of drop-forging—whether the drop-hammer with a board or a steam drop?

MR. BAKER—Mr. Chairman, referring just for a moment to that electric welding matter again, in all the samples that I ever saw of electric welding and I do not claim that I have seen even a type of all that has been done, the welding has always been done by placing the ends together and forcing it together while it was being heated, and in nearly every broken section I have seen, the cross section was greater just where the welding was than back of it, and I think that was the reason for breaking beside of, rather than at the welds. On the drop hammer matter, if you go down to Connecticut, or Brooklyn, you will find almost invariably board-drops and some pretty large ones. In Alliance, Ohio, you will find drop hammers from five tons down and not a board hammer in the shop. The board drops in our place were finally thrown aside. Our eastern friends do seem to understand just how to handle board drops, but when they get contrary they are bad for a man's morals. Sometimes foremen get out of patience with them and throw them aside, perhaps unnecessarily, but I do not think that board drops are as satisfactory as the steam drop, and for my own part, if I were erecting a forge shop to-day, I should not put in board drops at all, except for perhaps some special use.

MR. R. A. MCDONALD—I was in a shop a short time ago where the party had both kinds of drops and he did all his light work under the board drop and where he had heavy work, he used the steam drop. They run, I should judge, to probably 2,000 pound drop and they used it in some cases for finishing axes. The final finishing of the ax was done under the steam drop. The fancy work was done under the board drops.

MR. H. H. ANDERSON—Speaking about electric welding, don't you think that the cause of the failure of these welds is due more to the fact that the heating of the ends of the piece that is welded, opens the grain of the metal in that part immediately adjoining the weld? There is no work applied to it and the metal in cooling off back from the weld is left in an open condition. It is well known that in working hot metals,

unless there is work applied to it when cooling, it is weakened to a large extent.

In regard to that question about chilling the face of cast iron, I would like to ask Mr. Baker if he ever found any difficulty with the dies due to the cracking of the surface, when it came in contact with hot metals? I have found that in chilled dies, if we chill by means of uncovering them, they showed cracks very much quicker than in a good unchilled cast die. Where heavy pressures are applied though, a steel casting die is taking the place entirely of the cast iron. Where a great pressure is exacted, the cast iron die will not stand.

MR. BAKER—When it comes to the structural matter there may be plenty of cases in which the structural conditions are such that you could not do anything else but use a good steel die; but so far as the surface of the metal to stand wear is concerned, I should still think the cast iron preferable.

MR. R. A. MCDONALD—What is Mr. Baker's experience in plain dies for plain forging work?

MR. BAKER—Well a good deal depends on what you are doing with them. Take a steel die with much carbon in it and which has had hot iron pressed down on it, it will crack very freely on its face, and for all that class of work, I would want the chilled die.

MR. R. A. MCDONALD—I have seen cases where a steel die has been used for a year, during the same time a chilled die would have to be re-placed about every three months.

MR. BAKER—There is a great deal of work in which you could not use anything but a hardened steel die.

MR. HASLAM—With the present methods of forging, would you not consider that where there is much abrasion, it is practically impossible to use a steel die for a hot steel?

MR. BAKER—Take the steel die and it would chafe very much faster in sliding by the heavy hot metal, compared with dies of cast iron.

MR. DIESCHER—I know in rolls for small work the steel roll gets out of shape much sooner than the chilled roll.

MR. C. B. ALBREE—In the steam drop, have they had any trouble with the drip around the packing of the piston rod throw-

ing water on the dies or can they entirely obviate that? In the steam hammer such trouble often arises.

MR. BAKER—If there is any kind of trouble we don't have sooner or later in the case of the ordinary workman, I don't know what it is. But, of course, we have that. If the workmen don't keep their hammers moving, we have all sorts of trouble with water in the cylinders, and occasionally we get the top of the cylinder filled with water, and blown off by a careless man.

MR. L. C. MOORE—I would like to ask Mr. Baker if in any ordinary machine blacksmith shop there is a hammer made that will do away successfully with the blacksmith's helper?

MR. BAKER—I hardly think there is, but I want to tell you gentlemen, I visited the other day a concern who put in a steam drop hammer and used compressed air instead of steam to work it. They got a good driver and they used a big pair of flat dies and all sorts of pads, and they had a very fine blacksmith, but he still had to have a helper. He has a wonderful help in this hammer, yet I think that we might pretty nearly as well talk about doing without our wives as without a blacksmith's helper.

MR. L. C. MOORE—About the time of Professor Thompson's first perfected electric welding machine, I was connected with a concern manufacturing wire rope. We were all very much excited about doing away with brazing, going to weld all the wire with electricity. One of the first things we found out was that we could not weld below a certain diameter successfully for that purpose; another thing we found out was that we met with exactly the same trouble that all of the gentlemen have mentioned here to-night, the weld would break just a little ways back of the junction, perhaps a fraction of an inch; and another thing, the weld would swedge, or swell up right at the weld. We finally developed a pair of pliers that fit close around the wire, then in welding we turned on the current and quickly closed the pliers, and kept the wire at the same diameter at the weld. We did not stop it from breaking outside of the weld; it broke just the same because we used annealed wire. So the next move was to take the wire and weld it as it came from the blocks, afterwards annealing it. After that we never had trouble with the

wire breaking at the weld and on re-annealing made the metal so uniform from end to end, that it was almost impossible to tell where the weld had been made.

MR. BAKER—We have a question up now as to certain articles of steel breaking. They have been worked at one end and the only reason we have found is in the condition of the metal where the heat from the end joined the cold part of the bar. The only way out of it was to give the article a heat treatment. As to the other question, there has been a great deal of money backing the opinions of people who believe in commercial electric welding, but outside of special cases and forms, and which are very useful, we have not, I think, yet found general commercial electric welding in the proper sense of the word.

MR. KLINDWORTH—I think Mr. Anderson has the right theory about electric welding. The grain becomes so coarse that it loses strength, but if any subsequent work is put upon it, it will become as strong as before. Usually in electric welding the pieces do not receive any work and so the grain becomes coarse close to the weld, and it will break sooner than the other parts of the rod that are close grained. Of course, it does not break in the weld, because the section there has been increased on account of the ends having been forced together.

MR. STUCKI—The nature of the theory of electric welding is similar to the welding with Thermit. This material is very useful in making temporary repairs right on the spot and with least possible delay, but I agree with Mr. Baker that it is not a weld, but a fusion. I have seen pipes and locomotive frames joined successfully. In the first case, Thermit was simply used as an agent to produce heat, by which pieces of pipe were fused together; in the case of the locomotive frames, a slot is sawed out or milled between the two broken parts and the Thermit allowed to flow between and form the joint. In each case it is acknowledged that the nature of the adjoining materials changes, so much so, that for instance steel castings would have to be re-annealed after the welding, in order to obtain the original qualities.

The specimen of forging Mr. Baker had, I understand, was stretched from $7\frac{1}{2}''$ to 16″ by means of eccentric rolls of different speeds. Supposing we wanted to stretch it from $7\frac{1}{2}''$ to 20″,

would it be possible to figure with any degree of accuracy the relative diameters and speeds of the rolls?

MR. BAKER—The rolls in which that was made were running at 50 revolutions per minute, nearly a revolution a second. Now the rolls were of such diameter that the contact was less than one-third of the roll surface. I know there is a theory that the roll should be a certain diameter for each size iron we want. But when it comes to producing articles like this, if you had to put it into an eccentric roll two or three times you would fail. There is only one way to make it successfully and that is to put it in and make it while it is hot, very quickly. I perhaps am a crank, gentlemen, on the matter of rapid motion, but I did not think anything about any certain velocity with which the rolls in this case ought to run. I ran them as fast as I could.

MR. R. A. MCDONALD—The only question, Mr. Baker, as to the additional length, would simply be the diameter of your rolls. In getting your article longer and making it in one piece, it would only be a question of a larger diameter on your rolls.

MR. BAKER—Yes, because if you had your dies extending over one-third of the roll line, you would not be able to get in there far enough to get back with it. Now that was made on a 14″ roll. If you would take a 20″ roll, you would not be able to keep that down to $1\frac{5}{8}$″ wide, as it would spread sidewise too much. If I had not taken a smaller roll, I might have kept it only $1\frac{1}{2}$″ wide, while forging it down to $\frac{1}{8}$″ thick. So that when it comes to a certain forging it is a question of finding out how large rolls you need to have.

MR. R. A. MCDONALD—Would not the quality of the metal affect your conditions? Your flow of metal would be altogether different.

MR. ANDERSON—Would not the diameter of the roll cause it to spread more than any thing else? The larger surface of the roll pressing on the iron has a tendency to spread your iron out.

MR. BAKER—If you had your roll too large you would not forge it forward very much.

MR. MCMULLIN—Before electric welding was ever heard of, the problem of welding under pressure was thoroughly worked over. The Baldwin Locomotive Works, some years ago, put in a

hydraulic press for welding the limbs to the frames. A couple of men could weld them with heavy sledges, but a hydraulic press could not put a limb on to stay. One of the most reasonable theories I heard about it was from an uneducated helper in the shops. He said, "You try to weld by pressure and you press until you have pressed all the soft iron out, and have nothing but the cold surfaces to bring together." I think that is the cause of many failures in electric welding. Contrary to the experience of many of those present, I have seen electric welds break right in the weld, even though the section was the heaviest at the point. This, however, was due to dirt getting in the weld and would have given the same results whatever method of welding had been used. I have seen two pieces of iron covered with scale welded electrically, and the same welds break in the weld, while with any other method of welding than steady pressure, the scale would have been jarred out. Pressure welding does not jar out the slag in iron as does working under the hammer and most authorities ascribe the failure to weld iron by pressure to this fact.

In partial answer to Mr. Moore, I will describe a cheap power hammer. In the West I saw a blacksmith frequently get a cast-off pneumatic rock drill, set up a 12 x 12 stick of timber and bolt the drill to the timber in a vertical position. Make some kind of die to fit the drill chuck, connect to the air line, and he had a fair sort of hammer, and in a place like that, where there is an abundant supply of compressed air, it costs practically nothing. I saw such a thing described in one of our leading engineering papers less than six months ago as a new thing, but I have seen them used in the West ten years ago.

In Eastern Massachusetts I had charge of a forging shop where the problem of suitable drop-hammer boards was a heart breaking one. The company I worked for had been in the business for fifty years, and had had so much trouble that they engaged an expert in wood to travel round the country for several months selecting suitable boards, but somehow they seemed to have trouble with their boards. The noise made by a steam siren is nothing to a twisted board in a drop-hammer.

Speaking of cast iron dies, we had one job there, a loom crank made of $1\frac{3}{4}''$ round, 3" throw of crank, which we made in a drop hammer, using cast iron dies. The die had three impressions. It was about two feet long, 16" wide and one foot thick, and to have made that out of steel would have cost a small fortune. We got those dies made for about 3 cents per pound. It would pay to have a dozen made and throw half of them away, on a chance of having the other half good. They would make several thousand cranks before becoming worn out. We used them in a 1,200 pound drop with a fall of two feet, and they were very successful.

MR. R. A. MCDONALD—In how many operations would those cranks be made?

MR. MCMULLIN—In five operations, all performed by one man in one heat. At that time we were making between three and four thousand cranks every month.

MR. R. A. MCDONALD—Suppose you wanted to make a two or three or four way crank, how would you do it?

MR. MCMULLIN—The same as any other crank shaft, make them in line and twist them. These, however, had two cranks in line on a shaft. We had no trouble in working a dead length between the two cranks, there being about three or four feet, I believe, between them.

Someone asked the question here in regard to the kind of dies to use for general work. When a steam hammer comes out of the shop, it is usually equipped with a pair of cast iron dies, but in all the shops I ever worked, they made a pair of wrought iron dies with a steel face and got much better satisfaction. I remember but one forged die with a steel face that broke.

MR. R. A. MCDONALD—I made a hardened steel die and ran it for five years, rehardening it a number of times as the hardened face wore away.

MR. L. C. MOORE—I want to say a little more about electric welding. In the first place, I never knew it to prove a success with anything above, say ten carbon steel. The moment we got above that, it was impossible. Another thing some one spoke about, the absence of working the wire, I don't think you understood what I meant when describing the welding of the wire.

When we put the two ends together, we had a peculiar shaped pair of pliers and closed them on the wire while the current was still on, keeping it as nearly as possible to its original diameter. The molecules of metal, of course, change, but we got it back again to its original state by heating the whole coil of the wire to an annealing temperature. That actually worked the wire the same as though we hammered it, but on a small scale.

MR. R. A. MCDONALD—The Thompson Houston people had a plant for electric welding at one of our Expositions several years ago. The operator said they could weld any kind of metal. I sent down a couple pieces of alloy steel to have welded. He started to weld it and it fell to pieces when he put the pressure on, so he acknowledged that there was one kind of metal he could not weld. They have, however, in some cases, welded steel containing 1.30% carbon successfully. They have welded it, but in some cases it was not a perfect weld, and it would break. But I think they are welding even now, steel considerably higher than a 10 carbon. In welding ordinary steel, without re-annealing afterwards, the heating is too high for the best work afterwards of the steel. Any steel that has been subjected to heats of that kind, should be re-annealed to put it in a better condition. If it gets heated beyond a certain point, its grain becomes too coarse, then it is weaker than before, and will not stand any severe physical tests. It is weakened, and the only way to restore it is to melt it over.

MR. MCMULLIN—The Thompson Houston people had a welding plant at the World's Fair at Chicago, where I got a number of samples of welded work, flattened them out and tested them. They broke near the weld. That is the failing of all welds, however; there is a certain point where the upsetting stops. You work the upset down in making your weld and as it is hot beyond the point where the upset came to and where you do no work, that is the weakest point of your weld. That is the part of the weld that will break, as there is no chance to work it.

MR. BAKER—Perhaps in my paper I didn't state quite clearly enough that if the metal was welded where you could not give it sufficient work afterwards, it would leave it in a kind of an

ingot condition. But one more point on this: You take an upset, with say twice its area, and you create an ingot condition in that metal. Now you have worked it down to its original size. How much work have you given it? You have reduced it just one-half. You go to the rolling mill men and tell them you want an ingot and they will tell you they want that run down seven or eight times. You have only worked that little ingot down one diameter, whereas a rolling mill man would not think about giving you good steel if it was only worked that much.

MR. R. A. MCDONALD—On that question I think some people might make some objections. All people do not believe in big ingots making the best steel. Of course it is economy to make big ingots, and all soft steel is made in large ingots, simply because of the rolling advantages of big ingots. Now the Crucible steel makers, as a rule, do not make large ingots except for large work, because it is against their practice. So it is simply a question of what you want to get, and the question of the big ingots for lots of work does not always produce the best steel.

MR. ANDERSON—Can the Crucible steel makers produce an ingot of such a large size and get necessary results?

MR. R. A. MCDONALD—They could heat it and reduce it easily enough. Some do it.

MR. HASLAM—But is it not a fact that the more work you put on steel the better it is?

MR. R. A. MCDONALD—No, that is the old theory of iron, but not crucible steel. It is simply a question of economy to do it.

MR. MCMULLIN—Is it true about iron? I believe the reports of the U. S. Board showed no benefit beyond six workings, and but little for the fifth and sixth.

MR. ANDERSON—In most of the mills they desire to reduce it about four or five times to get the metal solid and bring it down to a good marketable product. I mean open-hearth steel.

MR. MOORE—I might tell you a little incident happening in our shop the other day: We had occasion to make a forging

about ten inches in diameter and twelve feet long. After turning it the machinist took a cold chisel and cut off the center; I happened to be looking at him and saw him throw his head back quick and say, "There is something coming out of that shaft." I smelt something right away. I told him to light a match and he did so, and that thing burned for ten minutes. I timed it. I would like to ask somebody if they can tell what that was? Was it a gas that had accumulated in the center of that shaft?

MR. R. A. MCDONALD—That in many cases is common, but you seldom hear of it. They don't usually tell things of that kind. But in experimenting, lots of ingots have been tested by drilling under water, and when you come to cavities gas escapes, causing bubbles. I have seen large ingots made by the open-hearth process that you could stick your hand in the center of them after they have been forged. Now to make a cavity there has got to be something in it. You often get a cavity down in the center or bottom of the ingot. They are in all shapes and sizes sometimes.

MR. KLINDWORTH—In forgings the steam hammer will do it frequently if the hammer is too light, and that suggests a question I was going to ask Mr. Baker; what his experience has been with hydraulic press and power hammer press forging. There are certain sizes where the hydraulic press is really necessary to get a good job.

MR. BAKER—You speak of the hydraulic press in welding. If you take a bar and use a hammer on it and draw the metal on the outside you form a hollow in the end. Take the press and you get the other result, that is a convex end. Therefore, in welding, if you use a press on a limb of a locomotive frame you would forge to the center of the V in the bar, and so stretch the V too wide. To properly work metal there is a certain sized head theoretically driven at a certain speed, which would bring the metal out altogether. That is the best worked metal you can get. The press would bring it out at the center and the light hammer will bring it out at the edge. Take armor plate for instance, I think they would save a lot of forg-

ing in that, I saw a 130,000 lbs. ingot at Homestead the other day forged in a press, and the edges were convex.

MR. MCMULLIN—In the Midvale Steel Co., they used to make ingots of about 72″ diameter for 12″ guns and they were forged under a 25-ton hammer and showed convex ends.

MR. BAKER—If the hammer is comparatively heavy enough the center will be forged out.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and fiftieth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's house, 410 Penn Ave., Pittsburgh, Pa., Tuesday evening, Dec. 20th, 1904, at 8:20 P. M. President J. M. Camp in the chair. Thirty-nine members and visitors were present.

The minutes of the previous meeting were read and approved. The Board of Direction reported that they had approved the following applications for membership and present same to the society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
W. O. AMSLER,	Pres., The Amsler Eng. Co. Empire Building, Pittsburg, Pa.	F. V. McMullin, Victor Buetner, Samuel Diescher.
JOS. M. ARMSTRONG,	Ass't Genl. Supt. of Mines, h., Ingram, Pa.	G. W. Schluderberg, W. W. Keefer, E. J. Taylor.
W. H. CHADBOURN, Jr.,	Ass't U. S. Engineer, - h., Beaver, Pa.	Wm. L. Sibert, H. C. Gould, T. P. Roberts.
E. E. CROCKER,	- - General Manager, - 323 Fourth Ave., Pittsburg, Pa.	C. W. Ridinger, T. F. Webster, J. L. Merrill.
GEO. R. DELAMATER,	Mechanical Engineer, - 305 Frick Building, Pittsburg, Pa.	Samuel Diescher, F. V. McMullin, C. H. Sample.
F. R. DRAVO,	Contractor, Lewis Block, Pittsburg, h., Sewickley, Pa.	J. M. Camp, Morris Knowles, T. H. Johnson.
L UIS A. HARDING,	Mechanical Engineer, - 305 Frick Building, Pittsburg, Pa.	Samuel Diescher, F. V. McMullin, C. H. Sample.
H. O. JONES,	- - - Supt. Pgh. Tube Co. - 21 Alpha Terrace, Beatty St., E. E. Pittsburg, Pa.	A. E. Duckham, H. W. Fisher, Richard Hirsch.

E. S. KINSELY,	Sales Agent, P. O. Box 1017, Pittsburg, Pa.	C. C. Schade, H. Gauerman, Willis Whited.
EDWARD LUCIUS,	Eng., 411 House Bldg. Pittsburg, Pa. h., Beaver Falls, Pa.	J. A. Atwood, A. R. Raymer, Jas. K. Lyons.
CHRISTOPHER MOGAN,	Supt. Pgh. Steel Co. Glassport, Pa.	S. Diescher, Samuel E. Diescher, Geo. T. Barnsley.
C. T. MYERS,	409 House Building, Pittsburg, Pa.	M. Greenwood, W. M. Judd, Louis P. Blum.
JAS. H. McROBERTS,	Consulting Engineer, 2107 Farmers Bank Bldg., Pittsburg, Pa.	Samuel Diescher, C. H. Sample, F. V. McMullin.

It was moved and seconded that the secretary be instructed to cast a ballot electing these applicants to membership.

The secretary then read a letter from Mr. J. L. Klindworth declining the nomination for secretary during the coming year, and announced that the board had named Mr. H. W. Craver as one of the three candidates for the position, the other two being Messrs. McMullin and Engstrom, both nominated in accordance with Art. III., Sec. 2.

PRESIDENT—One of the duties of the retiring president is to appoint a committee to look after the finances of the Society and audit the treasurer's accounts, as "the account, or financial books of the society shall be examined annually by a committee of three members of the society." I will appoint on that committee Mr. Barnsley, Mr. Worthington and Mr. Knowles.

MR. BARNSLEY—On behalf of the Reception Committee I wish to say that the next annual banquet will be on January 28th, 1905. Now this banquet will be an unusual occasion from the fact that it will be the celebration of the 25th anniversary of the society. Tickets will be five dollars.

PRESIDENT—Is there no other business? Then we are ready for the paper of the evening on the Nernst Lamp, by Mr. Roberts.

After hearing the paper and discussing it the meeting adjourned at 10 P. M.

THE NERNST LAMP.*

BY E. R. ROBERTS.
(Non-Member.)

While it would hardly seem necessary before an assembly of this character to give a brief description of the Nernst lamp and its history, yet it is very possible that some of you have been too busily engaged in your own pursuits to give this subject your consideration.

The fundamental principle of this lamp, that certain of the rare earths or refractory oxides will conduct electric current and give light after being heated to redness, was discovered by Dr. Nernst, the German scientist, in 1897. This has led to the development of a commercially perfect Nernst lamp in this country. The original invention of Dr. Nernst is embodied in the light-giving element or "glower" of the lamp as it is to-day. This glower, composed of a rare earth mixture, is made in the form of a small rod or pencil of chalk-like material with wire terminals at either end, one or more of these glowers being used to give lamps of different powers.

The Nernst lamp is in every sense a commercial illuminant and is now an important factor in modern illumination; the days when it excited interest chiefly as a scientific novelty are long since past.

Manufactured in different sizes, the light intensities of which range from that of high candle power incandescents to that of the modern 7½ ampere enclosed arcs, it not only creates a special field for itself, but with the exception of stage and sign lighting, certain parts of domestic lighting, such as bed rooms, closets, etc., and a few other special uses for light, the legitimate field of the Nernst is practically all that which is covered by modern gas and electric illuminants.

While in its general construction the Nernst is similar to that of the Arc, it properly belongs in the class of incandescent lamps,

*A lecture delivered before the Engineers' Society of Western Pennsylvania on December 20, 1904.

inasmuch as the glower gives light by virtue of its high state of incandescence, brought about by the heating action of the current flowing through it. The glower is an insulator when cold, but on being heated its resistance gradually decreases until it reaches a red heat, when, with 220 volts across the terminals, it starts to conduct current and give light. The heat generated by this current is not only sufficient to independently maintain the glower in an operating state, but causes the resistance to rapidly decrease still further, resulting in a greater and greater flow of current which would finally result in a ruptured glower if no external resistance with an opposite characteristic were used. For this reason it is essential that the "ballast," consisting of a fine iron wire enclosed in a glass tube, be connected in series with the glower; its function being to act as an automatic regulator to prevent the current in the glower circuit from rising materially above its normal value. In practice, the ballast performs its duty so well that the lamp will easily withstand an overload of 25 per cent. and may be operated continuously at 5 per cent. overload for extended periods without appreciable injury. A simple analogy will serve to illustrate the combind action of the glower and ballast. The glower in its runaway tendency may be likened to a train coasting down a grade; left to itself, its momentum and speed become greater and greater until finally disaster results unless frictional resistance is applied by means of the brakes so as to hold the speed fairly constant. The brakes of the train correspond to the ballast in the Nernst lamp.

Whereas the ballast is not appreciably impaired with age under conditions of normal voltage, the same cannot be said of the glower.

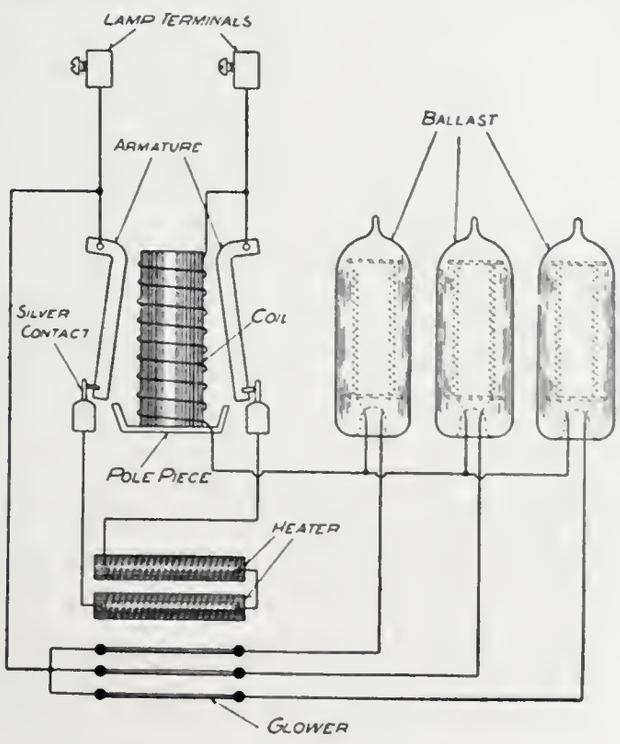
Before being used, the surface of the glower presents a smooth, white, porcelain or chalky appearance; after being in service say 500 hours, this surface is rough and crystalline in appearance. It is this change in the structure of the glower, from an amorphous to a crystalline state, that is supposed to cause a rise in its rated value on a constant potential circuit, which should not exceed 20 per cent. in 800 hours.

In the early part of the life of the lamp there is a decrease in intensity and the rated C. P. value is not reached until after

about 25 hours run; for instance, while the rated candle power of the single glower lamp is 50, the initial C. P. would average 60. This initial excess is not contracted for and may be considered as a gift to the consumer.

To bring the glower up to its starting point, corresponding to a temperature of about 1200° F., a small electric heater is employed, consisting of two or more small tubes of porcelain, about one and one-half inches long and one-quarter inches in diameter, overwound with a fine platinum wire, which in turn is held in place and protected from the intense glower heat by an outer coating of porcelain paste.

As stated above, after the heater has performed its function of lighting the glower, no further waste of energy in this circuit is necessary. For this reason a small electro-magnetic cutout is used, consisting of a magnet coil connected in series with the glower, an armature and the necessary contacts in the heater circuit. When the glower current flowing through the coil becomes strong enough, the armature is attracted, the contacts separated, and the heater disconnected from the line.



3 GLOWER LAMP

The accompanying figure is a diagram of the connections in a 3-glower lamp which may be taken as representative of all the other units.

The latter two elements of the lamp, namely, the ballast and cutout, are regarded as permanent fixtures of the lamp, their life being practically indefinite under normal conditions of operation. They are therefore mounted within the body of the lamp. The glowers and heater tubes, on the other hand, have a limited life and must be replaced from time to time as burnouts occur. These are mounted in a removable piece termed the holder, so as to be easy of access for renewal purposes. Mechanical and electrical connection between the lamp body and holder is made by means of a number of metal prongs mounted on the base of the holder. These are easily inserted by hand, and are held by friction, in corresponding metal sockets in the base of the lamp body.

We may therefore consider the Nernst lamp as composed of three main parts, viz., the lamp body, the holder, and the glass globe; corresponding to the lamp body, carbons and glassware of the arc.

After inserting the holder as explained above, the neck of the globe is inserted and held by three thumb screws in the base of the lamp body. The globe simply acts as a protection to the glowers in their operation, against air draughts and mechanical injury. Sufficient air in ventilation is allowed in the base of the lamp body so that the glowers practically operate in the open air; this being the atmosphere or medium in which they work most satisfactorily.

A standard glower, with the approximate dimensions given above, and taking .4 amperes at 210 volts is used altogether, and lamps of different sizes and powers are made by varying the number of glowers and providing the requisite ballasts and cutout.

At present the standard product consists of lamps, with one, two, three, four or six glowers, and maximum intensities from 25 to 500 candle power.

All of these units are adapted for use on 220 volt alternating current circuits of any frequency from 25 to 133 cycles inclusive, and with the exception of the last unit, these may be adapted to 110 volt circuits through the use of a "converter coil," which is suspended above the lamp proper.

When a holder becomes burnt out, the only maintenance work

necessary at the lamp itself is to wipe out the globe, remove the defective holder and replace it with a repaired holder. The subsequent renewal work on the defective holder is done at the repair shop. Without going any further into details, it is evident that Nernst and Arc lamp maintenance is much the same and does not require skilled labor for its execution. Reports from a number of large installations show that the cost of Nernst maintenance ranges from 5 mills to 1 cent per kilowatt hour, depending upon local conditions.

The Detroit Edison Company have kept a strict account of all labor and material necessary for the complete maintenance of the Nernst lamps on their circuits since the early part of this year, and find that the total average cost, including interest and depreciation, is .7 cent per kilowatt hour. They also figure that their Arc maintenance costs them practically the same and that incandescent maintenance cost .35 cent, not including labor. If the labor item is added and allowance made for the fact that Nernst lamps give twice the effective illumination obtained from incandescents per kilowatt hour expended, it follows that in this particular case, at least, the cost of Nernst maintenance *per effective candle power hour* is even less than for incandescent lamps.

The much-mooted question of *efficiency* never fails to bring out a difference of opinion as to the proper basis of comparison of the different modern light sources.

An arc lamp has both a nominal and an actual rating, the latter being based on photometric measurements, and the two differ widely. The rating of incandescent lamps is based on photometric measurements obtained while the lamp is rotating on a vertical axis, while the Welsbach and flat flame gas lights are rated in accordance with measurements obtained in the direction of maximum intensity. Obviously, the present commercial rating of these illuminants is absolutely unreliable because of the lack of a fair basis of comparison. There remain the mean spherical and mean hemispherical values of intensity to choose from; many say the former should be used; others prefer the latter. If a lamp is to be regarded as a mere producer of light, the mean spherical value is undoubtedly the proper selection. On the other hand, if the lamp is regarded as a producer of useful

illumination, opinion is gaining ground that the mean lower hemispherical value is the one desired. Comparing, for example, two lamps, each suspended near the ceiling of a reading room, the one throwing all its light in the upper hemisphere, the other all its light in the lower hemisphere; while the total amount of light given off, or the mean spherical candle power, might be the same in each case, there would be no hesitancy in selecting the latter as the superior illuminant. This statement is even more true for outdoor lighting, as the upward light would be entirely lost in space, whereas in the room, the ceiling might reflect back 25 per cent. of the light for useful purposes. Again, assuming it were possible to blacken the side of the sun which is turned away from the earth, that is to say, the surface of its most distant hemisphere, its mean spherical candle power would be reduced one-half, without impairing its value to the earth as a producer of daylight. From the standpoint of utility, therefore, it is obvious that the mean lower hemispherical candle power is by far the better basis for comparison.

On this basis, the recent reports of the National Electric Light Association indicate that the six-glower Nernst is 17 per cent. more efficient than the alternating current and 7 per cent. more efficient than the direct current multiple enclosed arc lamps. This in itself would establish the efficiency of the Nernst as being twice that of the incandescent, in view of the recognized standing of the latter as compared with the arc.

Recently, some work has been done at the Nernst Lamp Works in Pittsburg toward obtaining a more practical comparison of modern electric illuminants along the lines originally suggested by Mr. Wurts. A room approximately 20′x40′ was divided by means of an opaque curtain into two compartments, each 20′x20′ and both compartments furnished in an exactly similar manner, the only difference being that one compartment was lighted by Nernst lamps of different types and the other with Arc, Meridian and incandescent lamps. The illuminants in both rooms were arranged to the best possible advantage for each particular illuminant for effective illumination; each particular type of lamp being separately connected to a common switchboard, carrying an indicating watt meter which, in turn, may be quickly

connected to any particular circuit. The one room may thus be lighted by any one type of Nernst lamps, and the other by the Arc, Meridian or incandescent lamps at the same time, so that an observer stationed at the intersection of the dividing curtain and the wall may compare the general illumination of the two rooms. The average opinion of a number of observers as to the respective merits of the lamps, was based upon the general appearance of the rooms under the illumination furnished, and special visual tests in each room, such as the ability to read fine print. While the work is yet in an uncompleted state, the results so far point to the following conclusions:

6-glower lamp; 528 watts;	Equivalent in illuminating power to 7½ amp. multiple A. C. enclosed arc. Also 20 16 C. P. incandescent lamps.
4-glower lamp; 352 watts;	Equivalent in illuminating power to 6.6 amp. multiple A. C. enclosed arc.
3-glower lamp; 264 watts;	Equivalent to a 4-burner gas arc, or 9½ 16 C. P. incandescent lamps.
2-glower lamp; 176 watts;	Equivalent to 6 16 C. P. ordinary incandescent lamps.
1-glower lamp; 88 watts;	Equivalent to 1 ordinary Welsbach gas burner, or 3 16 C. P. incandescent lamps.

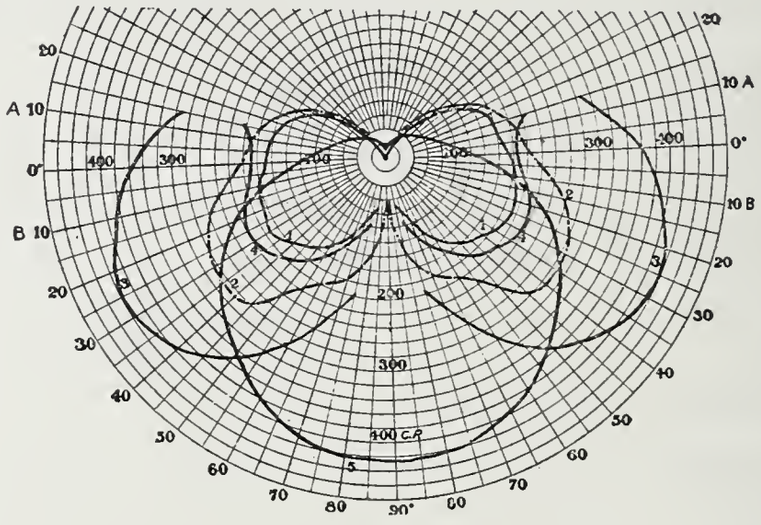
Photometric tests on the various units of the Nernst lamp, indicate that the efficiency increases with the number of glowers. This is readily accounted for by the resistance temperature characteristic of the glower and the fact that the several glowers tend to heat each other; this mutual heating effect being, of course, greater as the number of glowers is increased.

To rehearse briefly the other advantages of the Nernst lamp, we would first mention that of the "Sunlight Character" of the light produced. Owing to the peculiar composition of the glower and the extremely high temperature at which it operates, the color of the light is very close to that of sunlight. The lamp therefore

holds a distinct advantage in this respect over other lights for store illumination, where it is important that colors be presented in their natural values, so as to facilitate the matching of colors or selection of colored goods by the customer. In comparison, the Arc has a violet color, the incandescent a reddish yellow and the gas mantle burner a greenish yellow light.

This particular feature of the Nernst lamp has already won for it pre-eminence in the special field of Art Gallery lighting.

Up-to-date experts on illumination are fast coming to the decision that an overhead system of lighting is the one to be desired and that the days of the low hanging chandelier are numbered. By "overhead" system we refer to one in which the lights are kept at a good elevation, so as to be removed from the ordinary range of vision. This, of course, is the natural and proper method, because when the lamps are placed only a short distance above the plane of vision, there is always a bright light in the field of vision. This not only decreases the effective illumination, owing to the contraction of the pupil of the eye, but it is a frequent cause of eye-strain.



As may be seen from the accompanying curves about 90 per cent. of the light from the Nernst lamp, is given off in the lower hemisphere; the maximum intensity being obtained directly beneath the lamp. In this respect, it is therefore especially adapted to the most approval and natural system of lighting.

The Nernst system is also rendered extremely flexible owing to the different units available as enumerated above, and it is possible to use both large and small units in the same installa-

tion and obtain an illumination uniform throughout, both in quantity and quality, which is far superior to a mixed system of Arcs and incandescents, giving an illumination of mixed color and quality.

The well known advantage of the high voltage of the Nernst in the saving of line losses and wiring needs no discussion and your attention is simply called to the fact that the lighting capacity of any part of the incandescent supply circuit may be increased four fold by substituting Nernst lamps, assuming the circuit to be previously loaded to its full capacity with 110 volt incandescents.

Perfect steadiness of the light, absence of shadow, 100 per cent. power factor and general neat appearance of the lamp itself, are all advantages which may be claimed for the Nernst lamp over the modern A. C. multiple enclosed arc.

The following reasons may be advanced showing that the Nernst lamp is principally a Central Station proposition:

As a comparatively new illuminant, its requirements from the maintenance standpoint are apt to cause criticism and prejudice, unless cared for in an intelligent manner. This the Central Station is best prepared to give.

Its high voltage feature will effect a saving in the copper investment.

Its efficiency will enable the Company to increase the lighting capacity of its station equipment.

It is not effected to so great an extent, as are incandescent lamps by continuous overload, and the regulation need not be so exact.

DISCUSSION.

MR. R. L. FRINK—You show in one illustration that it takes $3\frac{1}{2}$ amperes for starting the lamp. Does that have any effect on the specifications in wiring?

MR. E. R. ROBERTS—We have not found it so. The high initial current lasts only for a small fraction of a second . Besides the lamps are hardly ever thrown on all at one time, so that the wattage at any one instant is hardly likely to exceed the allowable wattage of the circuit.

MR. R. L. FRINK—Suppose we had a fused circuit carrying six lights operated from one switch. If we threw on all six lights, would it blow the fuse?

MR. E. R. ROBERTS—That has been tried and it seems that the over-load effect takes place too quickly for the fuse to blow.

MR. R. L. FRINK—Do you make a lamp that operates with direct current?

MR. E. R. ROBERTS—Not yet. It is rather curious that the practice in Europe is altogether on direct current, whereas it is just the opposite in this country.

MR. J. M. CAMP—The materials in the glowers are not very much of a secret. Can you give us the names of those elements?

MR. E. R. ROBERTS—The glower is composed of several of the rare earths, as Yttrium, Erbium, Cerium, Zirconium, Uranium, Thorium, and others of that group. The standard glower is made from a mixture of the metal oxides of these elements.

MR. F. W. WINTER—I had the pleasure of meeting Dr. Nernst in the summer of 1898 when he was in this country and he gave an exhibition in the Patent Office with reference to his lamp. We saw the peculiar sight of an electric lamp being lighted by a match. He had a small exhibition lamp which was put in the circuit and the current turned on. He then lighted an ordinary match and held it under the glower, and before the match stick was consumed the glower had been heated sufficiently to become a conductor. The fact that these rare earths were conductors at a high temperature was known long before Dr. Nernst made his announcement. There is a class of materials known as electrolites which are non-conductors when cold, but conductors when at a high temperature. There are very many materials of the kind; porcelain, lime, and magnesia are some of the more common earths that act in that way. As early as the Exposition in Paris in 1878 there was exhibited a curiosity in the form of a lamp called Jablochkoff's Candle, named after the inventor. It consisted of a small block of porcelain mounted between two terminals; a conductor would be placed across the terminal in contact with the porcelain. The conductor was any strip of metal that would conduct the current. That was to start the conduction. The current flowing through the conductor heated the porcelain

and finally the latter became a conductor and glowed. By that time the heat had become so great that the metal conductor was entirely burned away, but the porcelain would keep on glowing as long as the current was maintained. That was far from a commercial proposition, as it made it necessary to apply a metal conductor each time the device was used. But it shows how old, really, is the principle, broadly considered, of the Nernst lamp. It was followed a number of years after by various applications of conductors of the second class for producing light. I remember one which consisted of a small body of magnesia with a metal conductor passing through it. When the current was turned on, the heat from the conductor would gradually heat the magnesia until the latter became a conductor and glower. Obviously this was a very wasteful device, because the metal conductor was consuming a certain amount of current without producing light. It is not a commercial proposition. I think that Dr. Nernst's discovery was that greater efficiency in light effect could be obtained by using the rare earths, instead of the more common ones, a most important discovery from a commercial point of view; also an arrangement for automatically heating the glower and then cutting out the heater so as to stop the waste of current through the heater. That was the real problem that had to be met in order to make the lamp a commercial success.

Mr. W. Whited—Speaking of the Jablochkoff lights, I know they were tried in New York City on a commercial scale about 1880 or 1881. As I understand it, the way they used what they called candles, which consisted of two porcelain rods 1/16" or so apart, vertical and parallel with a metal connection across the top, which burned out when the current started. They were used with alternating current, and an arc was carried across the tops which gradually burned away the rods. If the current stopped for any reason, it could not be started again through a partly burned candle, a new candle had to be substituted.

Mr. F. W. Winter—That was a modification of the one that I described, and it was a later development. It had two conductors practically parallel with a block of porcelain between, which was heated by the arc. The porcelain was rather small so that the voltage would carry the arc across the gap between the two con-

ductors which gradually wore down and the porcelain also. It was in reality an incandescent arc, in which the arc heated the block of porcelain to incandescence.

MR. E. R. ROBERTS—Great credit is due Dr. Nernst that he discovered a commercial composition for the glower. Magnesium glowers had been made prior to his discovery, which were not, however, of any practical value. Early lamps made by Dr. Nernst were non-automatic in their operation, and the heater was operated by a simple switch in the body of the lamp. As soon as the glower became sufficiently heated to light up, this switch was thrown out. The cut-out was really developed in this country.

The early records indicate that the manufacture of cut-outs was first taken up by Mr. Henry Noel Potter, an assistant of Dr. Nernst. Mr. Potter developed some very neat designs in the thermostatic cut-out, in which both the ballast and cut-out was enclosed in a common glass tube, so that the heat from the ballast wire would cause the expansion of certain metals and the separation of certain contacts. All the lamps at the late Paris Exposition were constructed without electrical heaters, and the man in lighting the lamps, passed around among them with a torch and started them as he would ordinary gas lamps.

MR. J. K. LYONS—The breakage of globes is quite an item in maintenance and if those glowers will work exposed to the atmosphere the maintenance would be still further lowered.

MR. E. R. ROBERTS—I don't think there is much chance of such practice being adopted commercially. The globe is really necessary to give better diffusion of the light. The naked glower gives too bright a light. It would be injurious to the eyes and like the open arc would cause a dense shadow. Besides I don't think it would be allowable, from the underwriter's standpoint, to leave an incandescent body naked in that way.

MR. F. W. H. CLAY—Have there been any experiments made having in view a sliding contact of some sort that the amount of light may be regulated?

MR. E. R. ROBERTS—We have lately developed an attachment by means of which it is possible to throw half the number of glowers out of service. Either half or all of the normal candle power may be used. Any sliding metal contact we could use

there would melt off on the incandescent portion of the glower. The platinum terminals are connected to the glower through a bead consisting of fused glower material, and that bead being larger than the other portion of the glower is kept cooler by the greater radiating surface. We could not have a sliding metal contact on the glower proper under such a high state of incandescence. There is no metal that would stand it.

FACTS CONCERNING PATENTS NOT GENERALLY UNDERSTOOD, OR OF GENERAL INTEREST TO ENGINEERS*.

BY FREDERICK W. WINTER,
Member Engineers' Society of Western Penn'a.

From scientific and technical engineering subjects to patent law is a far cry, and a paper of the character of this before an engineering society is proper merely because a large number of inventions emanate from engineers, and especially from mechanical men. Engineers should, therefore, have a general knowledge as to what rights they have in inventions made by themselves, or by those associated with them, the manner of securing and enforcing those rights, and, in general, to be in possession of such information on the subject as to be able to act advisedly in regard thereto.

Basis of our Patent System. The patent statutes of the United States are based upon Article 1, Section 8, of the Constitution, which provides that Congress shall have power to promote the progress of science and useful arts by securing for limited times to inventors the exclusive right to their respective discoveries.

This constitutional provision gives the underlying principle of our patent statutes, and shows that the reward of the inventor is not the primary object aimed at. But it is a necessary incident. The framers of the constitution perceived that the progress of science and the useful arts could best be promoted by furnishing an incentive to make improvements, and that the best incentive is some personal reward or advantage to the inventor. Accordingly an inventor for a certain period is given an exclusive right to his inventions and discoveries; that is, a monopoly. As a consideration he is required to describe and illustrate the invention in his patent specification and drawings so fully and clearly that a person skilled in the industry to which the invention relates can make and use the invention; to the end that after the monopoly has expired, the public will be able to use and derive benefit therefrom.

*Address delivered before Mechanical Section, Dec. 1, 1904.

Therefore an inventor applying for a patent must disclose his entire invention, the principle thereof, and the best manner of applying the same. He cannot withhold any part thereof; otherwise the patent will be void. If he wishes to keep the whole or any part of his invention secret, the patent statutes give him no aid. This statement is ventured because the writer has been asked to secure patents for inventions which the inventors did not care to disclose fully even to their attorney. Clearly all such efforts are futile.

What is Patentable. The statutes provide for the grant of patents for new and useful arts, machines, manufactures, compositions of matter, improvements, and designs.

The term *"art"* covers what are ordinarily known as methods or processes, where the improvement consists in the manner or mode of accomplishing the result, as distinguished from the mechanical appliances necessary for this purpose.

The term *"machine"* is self-explanatory.

The term *"composition of matter"* covers all mixtures of several ingredients whether chemical combinations or mechanical mixtures. Soaps, powders, paints, etc., are examples of well-known compositions of matter.

A *"manufacture"* in the meaning of the patent statutes is anything made by the hand of man and which is subject to manufacture and sale. This term is a broad and elastic one, and the interpretation given to it by the courts bring within it all inventions which cannot properly be classified under the other heads.

The term *"improvement"* in the statutes is largely superfluous, for in a sense every improved device is a new device; or, *vice versa,* most new devices are merely improvements over prior devices. In the history of our patent system there have been but few generically new devices or processes.

The inventor need not concern himself under which one of the statutory classes his invention belongs. Neither do the Patent Office and the courts concern themselves with this question, it being sufficient that the invention is new, and that it marks an advance in science and the useful arts. The statutory classes of mechanical inventions will be stretched to cover it.

The term *"design"* in the patent statutes has a different meaning from what it has in engineering, where it is often used to mean a new plan or arrangement of mechanical parts for getting new or improved functions. For instance, a new design of motor is a new motor.

All such matters in the eye of the patent statutes are subjects for mechanical, and not for design, patents. The term "design" in the statutes is limited to matters of ornament or configuration appealing to the aesthetic sense and not to utility; such as a new design for spoons, jewelry, vases, and the like.

Utility. An improvement to be patentable must be *useful.* This does not mean that the device must be more efficient or economical than prior devices of the same character. It is useful within the meaning of the statute if it is capable of producing a result, and that result is a good one, even though it may not be an advance upon prior devices of the same kind. The degree of utility is not inquired into by the Patent Office.

If a device is incapable of producing any result whatsoever, it is inoperative and not patentable. So, too, if the device is injurious to the morals, health, or good order of society, it is not "useful" within the meaning of the patent statutes. Upon this ground the Patent Office refuses to grant, and the courts refuse to sustain, patents for deleterious compositions and compounds of food products and the like, and for devices which can be used only for immoral or unlawful purposes. The more completely such an invention could perform its functions the more objectionable it would be for want of utility.

If, however, a device is capable of a good result it is patentable, even though it may be used for some unlawful or immoral purpose. The evil in such case is not inherent in the invention, but is a fault of the user, for which the latter, and not the inventor, should be punished.

Subject to the exception in regard to the utility of an invention it is a general rule that all changes or improvements, whether mechanical, electrical, chemical, structural, or otherwise, in a method or process, tool, machine, appliance, device, manufactured article or composition of matter, in all arts, are patentable, providing they are *new* and are the result of *invention.*

The statutory classes of invention have been given a sufficiently broad and elastic interpretation to cover the whole range of human activities and industries.

Invention. As to what constitutes invention no general rule can be laid down. There are many improvements which are the natural result of the advancement of an industry and which are suggested by many persons whenever the occasion demands. There also are many changes which are merely the expected skill of an ordinary mechanic working in those lines. All such changes are not "inventions" within the meaning of the patent statutes, and are not patentable.

In general, invention may be said to consist in bringing forth that which theretofore was hidden to persons skilled in that particular art. The amount of change necessary to constitute invention may be very small, or may be required to be quite radical, depending upon various factors, but principally upon the advantages and results following from the change. If the benefits are very great, and the public and manufacturers are anxious to adopt the improvement as soon as known, it will be held to show that even a very slight change was the doing of something which before was hidden, and hence to be an invention. On the other hand, where there is no marked resulting advantage, the courts require a greater degree of change in order to find the presence of invention.

Novelty. The question of the newness or novelty of an invention is purely one of fact, and one upon which no opinion can be expressed without a detailed knowledge or examination of the art to which the invention relates. Under the statute, an invention is not new if it was:—

(1) Patented in this or any foreign country before the applicant's invention or discovery thereof, or more than two years prior to the application for patent;

(2) Described in a printed publication in this or any foreign country prior to such invention or discovery, or more than two years prior to the application;

(3) Known or used in this country prior to such invention or discovery, or

(4) In public use or on sale in this country for more than two years prior to the application.

It follows that knowledge or use of an invention in a foreign country does not affect a patent granted in this country, unless such invention was either patented or described in some printed publication.

Novelty can be determined only by an examination of all prior patents, publications, and uses in the same and analogous classes of inventions. This, to be thorough, covers a very wide range.

Term of Patent. All mechanical patents are granted for the uniform term of 17 years. This is not now affected by the existence of any prior shorter term foreign patents for the same invention, the only requirement being that if a patent is first taken out in a foreign country, the application in this country must be filed within 12 months after the filing of the foreign application. The term of 17 years can be extended only by a special act of Congress, and this has not been done in any case, and is not likely to be done.

In case there is a material error in the patent, or if it is inoperative or invalid by reason of a defective or insufficient specification or claim, it may be reissued, but such reissued patent will continue in force only for the unexpired term of the original patent.

Design patents are granted for terms of $3\frac{1}{2}$, 7, or 14 years, at the option of the applicant. He must make his selection of the term at the time he files his application. It cannot be made thereafter.

The Right Granted by Patent. All patents give an exclusive right during the term of the patent to (1) make, (2) use and (3) sell the invention covered thereby. Infringement therefore may occur either by making, or by using, or by selling the device. Where one party manufactures a patented device, another party sells it, and a third party uses it, they are each liable for the entire infringement, and the patentee can choose which of the three he will sue, thus being able to select the one most able to respond in damages.

Patent rights extend to all of the United States and territories, but not beyond the same. *Vice versa,* patents granted in foreign countries give no protection in this country. Therefore it is no aid to the protection in this country to also take out patents in foreign countries. The seller or user in this country of an article manufactured abroad will be liable for infringement of any United States patent covering said article.

A patent gives an exclusive right only for that which is distinctly *claimed.* If no sufficient claim is made, the courts will give no relief, even if the invention is exceedingly valuable. The utmost care should therefore be exercised in drawing the claims of a patent. It is possible to so restrict the claims for a very valuable invention that it will be easy for others to devise forms of apparatus which accomplish the same result but do not infringe the patent. The claims should cover all possible mechanical embodiments of the principle of the invention, so that others, even though they originate new mechanical constructions or combinations, cannot avoid infringement.

Patent claims usually are drawn to combinations of the various elements which constitute the new device. Infringement does not exist unless all elements of the claims are employed by the defendant. In other words, the combination of a claim must be used in its entirety or else infringement does not exist. It is therefore essential that the claims, or at least the broad claim, should contain no element or limitation which is not absolutely essential to the principle of the invention. Brevity in patent claims is desirable.

The monopoly does not begin until the patent has actually issued. While the application is still pending in the Patent Office the inventor has no right to sue others for infringement.

Several Claimants for Same Invention. It is never absolutely certain that a patent can be obtained until it is actually granted. Several parties may apply for a patent on the same invention, and in that case the applications will be put in what are known as "interference" proceedings, in which the parties will be required to take testimony to prove who is the first inventor, and the patent will be granted accordingly.

The first inventor is the person who first perfected the invention and put it into a form capable of actual use, or, as it is technically known, "reduced the invention to practice." The best evidence of a completed invention is an actual commercial use thereof. But there is a rule that the filing of an allowable application for patent is a "constructive reduction to practice" and has the same force and effect in a contest on priority of invention as an actual commercial use.

While the general rule is that the first inventor is he who first reduced the invention to practice, an exception is recognized in favor of a party who was the first to conceive of the invention, but the last to reduce it to actual practice, providing he was using reasonable diligence in perfecting and adapting the same. What constitutes reasonable diligence depends upon the particular circumstances of each case. The means at the command of a person, his employment, and other surrounding circumstances, his health, the complication of the invention, and cost of perfecting it, are all factors which enter into this question. What the law requires is reasonable, and not the utmost, diligence. But the Patent Office does not look with favor upon delays, and it requires a good excuse in all cases. The theory is that the party who first adapts an invention for actual use should not be barred by the stale claims of a prior conceiver who has slept on his rights.

The Patent Office does not require mechanical perfection, but will allow an application which shows a theoretically operative device and clearly describes the principle thereof. Since the filing of such an allowable application, in a contest of priority of invention, has the same force and effect as an actual use of the device, it is advisable for inventors to make application for patent as soon as they have theoretically perfected the invention and not wait until they can put it into actual use, unless, of course, they are so situated that they can speedily give the invention an actual test.

Even after a patent is granted another party may file an application for the same invention and be put in interference with the patent. If he is able to prove, by evidence which does not admit of a doubt, that he first completed the invention, a patent

will also be granted to him. The Patent Office, however, cannot call back or annul the patent first granted. It will merely be decided that the patentee was not the first inventor and a patent will be granted to the applicant.

The Patent Office has no jurisdiction over a patent after it is granted except to declare an interference between it and a subsequent application, or to grant a reissue of the patent in case it is invalid or inoperative by reason of a defective or insufficient specification.

Patent Does not Guarantee That Invention Can be Used. The grant of a patent is no indication that the device covered thereby can be used without infringing prior patents. This is a point upon which much misunderstanding exists. Many persons assume that because the Patent Office grants a patent, the patentee has a perfect right to use the device covered thereby. This is an error. The Patent Office does not pass upon the question of infringement, but merely decides whether the applicant has made a patentable improvement over prior devices. Most patents cover mere improvements upon prior devices, and it frequently happens that there are still in force prior patents which cover fundamental principles of the device, and which will be infringed by the improved device, if the latter performs the same function by the same or equivalent means. To illustrate: The original Bell patent covered the fundamental principles of transmitting speech electrically. Within a few years thereafter, and during the life of that patent, others invented and patented many different forms of transmitters which were improvements upon the transmitter shown in the Bell patent. These improvements were clearly patentable; but they were just as clearly infringements of the Bell patent, because they of necessity operated on the principle covered by that patent.

But in many arts to-day the existing patents are limited to such specific improvements that other improvements do not infringe.

All patents are *prima facie* valid. They may, however, be invalid for many reasons. The Examiners in the Patent Office are human and liable to error. They also have not available the material for all grounds upon which a patent might be refused

or invalidated. Patents can be refused upon publications or descriptions of the invention in scientific and technical journals or books in all languages. The Patent Office has not files of many publications, and many which they have are not available within the limited time in which the Examiner must dispose of a case. So, too, a patent may be refused upon a prior use of the invention in some remote part of the United States, and which may be known to only a limited number of persons. Obviously, the Patent Office is not in a position to know of all uses.

There are therefore many elements entering into the validity of a patent upon which the Patent Office passes no opinion. A more extended examination through periodicals and prior uses than it is possible for the Patent Office to make, will frequently show, either that the patent is entirely void, or that it must be so restricted that infringement can be avoided.

Who May Obtain a Patent. It is essential to the validity of a patent that it be granted on an application signed and sworn to by the original and first inventor or inventors, or by his or their executors or administrators. No other person, even with the consent of the inventor, can sign or swear to an application that will support a valid patent. The Patent Office has no means of ascertaining these facts and will necessarily be governed by the oath of the application. Should it, however, afterwards develop that the party making the application was not the inventor, the patent will be invalid.

The fact that a person furnishes capital, machinery, or material for developing the invention, gives him no right to make or join in the application for patent. Such person may acquire an interest under the patent, but this can only be done by an assignment executed by the inventor and transferring to him the whole, or any fractional portion, of the entire right to the invention and to the patent. If such assignment is recorded in time the patent will be issued to the assignee, or jointly to the assignee and the inventor, as the case may be.

The builder of a new machine or device is not the inventor if he did not himself originate the ideas or principles contained in such device. In other words, an inventor may employ others to construct and mechanically perfect his invention without losing

his exclusive right thereto, and without giving the mechanic who constructs it any right to the patent, unless it has been agreed upon by contract between the parties. Even in that case the mechanic will take his right only by reason of the contract and under a properly executed assignment.

If a person conceives the general plan of an invention and employs another to construct and perfect the same, and the latter under such employment originates improvements which are included in, or, as the court said in one case, are ancillary to, the general plan, such improvements nevertheless belong to the person furnishing the general plan and can be included in any patent for which he may apply.

All patents and patent rights can be assigned without restriction by the owner or owners thereof, either before or after the patent is granted, or even before the application for patent is filed. All such assignments must be executed by the party or parties who have the legal title to the invention at the time the assignment is made. An assignment may cover the whole right under the patent or any fractional portion thereof.

An assignment must be recorded in the Patent Office within three months after the execution thereof. Otherwise it will be void as against a subsequent purchaser for a valuable consideration and without notice of such assignment.

Patent Rights Between Employer and Employe. Employes as well as employers are entitled to their own inventions and to patents granted therefor. This right can be modified by contract, but in the absence of a contract to the contrary an employé is entitled to a patent for any invention which he makes, even though it may relate to the business of his employer. If he develops the invention in the time, and at the expense, and with the tools and material of his employer, then the latter will have an implied license or shop-right to use such invention in his business, but he cannot demand an assignment of the patent.

Employers who wish to secure inventions relating to their own business, which are made by others while in their employ, should have a contract with the employé. Even with such a contract the employer cannot apply for a patent in his own name, but

the patent must be applied for by the employe and assigned to the employer.

Joint Owners of Patents. Patents may be owned jointly by two or more parties, and these may have different fractional interests. A common misapprehension is that one joint owner of a patent cannot make, use, or sell the patented invention without the consent of, and without accounting for profits to, his co-owners. This is an error. In the absence of a contract to the contrary, any co-owner of a patent, no matter what fractional interest he may hold, is free to assign his interest in the patent, or to manufacture, use, and sell the patented device, or license others to do so, without the consent of his co-owners and without accounting for any part of the profits.

If, therefore, a person owns merely a one-hundredth share of the entire patent right, he may manufacture, sell or use the patented device without the consent of, or accounting for the profits to, the owners of the other ninety-nine one-hundredths. By reason of superior facilities for manufacture, or superior business ability, he may even entirely monopolize the field so as to practically exclude his co-owners from deriving any income whatsoever from their share of the patent. He is nevertheless entirely within his right. The only way this can be prevented is by a properly drawn contract between the co-owners.

Applications for Patent. Only a small percentage of patent applications are allowed as first filed. Generally the officials find some objections against the specification or claims, generally the latter. It frequently happens that a patent is not secured until after repeated considerations. An inventor should therefore not be discouraged because in the first instance his application is rejected. The rules give ample opportunity for overcoming rejections either by amendment or argument, or both, or even appeal to a higher tribunal.

Amendments may be made to applications at any time prior to their allowance, so as to more clearly or definitely claim the invention, or to restrict the specification and claims to that which is found after examination to be new. But no new or additional matter can be incorporated in an application after it is filed. Anything which is found either in the specification, claims, drawing

or model as originally filed in the Patent Office, is not new matter, but anything outside or beyond these will be refused, or if added, the patent will be invalidated thereby. This rule is very strictly followed.

The writer desires to emphasize this point as his experience is that many inventors think that references which the Patent Office cite against their application can be evaded by making changes or alterations in, or additions to, the application. All efforts in this direction are futile. Modifications and alterations which come within the scope of the claims allowed in the application are covered and protected by the patent. But all other alterations or modifications are not protected by the patent. If they are of sufficient importance to constitute an independent invention, they can be protected by making a separate application therefor.

Marking Patented Articles. The owner of a patent must mark the patented articles plainly with the word "patented," or similar word, together with the date of the patent, or otherwise give sufficient notice to the public that the device is patented. The failure to so mark will prevent the recovery of damages for infringement occurring prior to actual notice of the patent to the infringer.

No person should mark an unpatented article with the word "patent" or other designation which would lead the public to believe that the article is patented. For each such false marking, with intent to deceive the public, the marker is liable to a penalty of $100. While the application is still pending the manufactured articles can be marked "patent pending" or "patent applied for." This will warn the public, and in most cases will prevent infringement.

Caveat. There is a common misapprehension that a caveat is a short term patent. On the contrary it is a mere notice to the Patent Office that the party has made an invention and wishes further time to mature the same. It continues in force for one year, and it may be renewed from year to year by the payment of the required government fee. If during the term of the caveat, or any renewal thereof, another person files an application for patent for the invention shown in the caveat, the caveator will

be notified thereof and will be required to file his application within three months from the time of receiving the notice. The two applications will then be put in interference and testimony will be taken to prove who was the first inventor, and the patent will be granted to such party.

A caveat is not a patent at all, nor even an application for patent, nor can it by any possibility mature into an application. No one can be sued for infringement under a caveat. It is a mere notice to the Patent Office, and if the caveator wishes afterwards to obtain a patent he must file a regular application in the usual way.

Foreign Patents. The patent laws of no two countries are the same, and a device which is patentable in this country may not be patentable in foreign countries, and, *vice versa*, devices which are not patentable here may be patentable in some foreign country. In Germany it is difficult to obtain patents, the laws and their interpretation being very strict. Many of the small improvements which are patentable in this country find no favor under the German law. In other foreign countries, notably Belgium and France, no examination into the novelty or patentability of the invention is made, but the patent is granted as a matter of course. But this does not mean that the patent will be held valid, as it may be overthrown if it is found that the invention was not new in that country at the time the application was made. It is essential therefore in these countries that the prior state of the art be thoroughly investigated before the patent claims are drawn.

The cost of obtaining a patent in most foreign countries is greater than in the United States, and the conditions of maintaining the patent are somewhat burdensome. In this country, no taxes or renewal fees are necessary, nor is the patentee even compelled to manufacture the patented device or put it into use. In most foreign countries the patents are subject to annual taxes or renewal fees. These vary in the different countries, being generally quite low the first few years of the patent term, but gradually increase. Such taxes amount to a considerable sum in the aggregate, and if the patent is not producing a revenue they are a burden.

So, too, in most foreign countries the inventor must put the invention into actual use in that country, or at least make such arrangements for manufacturing and so advertise the fact, that any person wishing to procure the patented article can be supplied. The manufacture of the articles in this country and importation into foreign countries does not comply with this provision of the laws of those countries.

In most foreign countries patents must be applied for before corresponding patents are issued in this or any other country. Canada is an exception, as patents can be applied for within a year after the issue of a patent in another country.

DISCUSSION.

MR. F. V. MCMULLIN, M. Eng. So. W. Pa.—Mr. Winter, you say "Employers who wish to secure inventions relating to their own business, which are made by others while in their employ, should have a contract with the employee." Is that contract worth the drawing? Do not the courts hold that a man cannot mortgage the product of his brain?

MR. F. W. WINTER—It depends on the contract. The courts do hold that, but nevertheless a valid contract can be drawn. Any contract between employer and employee should be drawn very carefully. The employer should be very careful not to demand all inventions of the employee, past, present, and future, because if he does the court is liable to say the contract is a mortgage on the employee's brain, and therefore not valid. The contract should specify what particular inventions are to go to the employer. It should be supported by some valuable consideration, more than the mere wages of the employee. It should also clearly state what rights the employer is to have in the invention, and if he is to own the patent this should be definitely stated. I have a case now that arose on such a contract, and which we expect to defeat, first, on the ground that the contract does not specify the particular invention which is now being sought to be brought under it; second, that there was no consideration for an invention which is now proven to be very valuable, except the mere payment of the prevailing machinist wages; and third, that the contract is not definite as to the rights which the employer

was to take. Our view of that contract is that there was no consideration for the inventions which are sought to be conveyed, and that the contract is indefinite as to its subject-matter. Such contracts should be definite as to just what right the employer is to take in the invention. The contract I speak of states that the employer should take the benefit and use of the invention. We hold that this language gives no right to an assignment of the patent.

These contracts can be made worth the drawing if they are properly drawn, but you are entirely right in assuming that they cannot place a mortgage on a man's brain. You can make a general contract with an employee that any inventions that he makes, with reference to, say alternating motors, while in your employ, shall be your property; that would be sufficiently specific as to the subject-matter. But if the contract says, "all inventions which the employee may make," then it is not sufficiently specific.

MR. H. C. CRONEMEYER, M. Eng. So. W. Pa.—If an employee makes an invention to which his employer has a shop right, does that shop right also extend to other works owned by the same employer? For example: A large corporation has a number of works and an employee in one of their works makes a valuable invention which is used at that particular works, without payment to the employee. Has the company a right to use the same invention in its other works also without making any compensation to the inventor?

MR. F. W. WINTER—Works which belong to the employer can make use of those inventions. If the inventor is employed, for instance by the Carnegie Steel Company, that Company would have a right to use that invention in any other works which it owns and controls; but other companies who are merely associated in a business arrangement with the Carnegie Steel Company, such as the other constituent companies of the United States Steel Corporation, would not be entitled to use it in their works, because the inventor is not the employee of the United States Steel Corporation. Most large concerns have more than a single works, and if they have contracts with their employees with reference to inventions, it seems only reasonable to suppose they would want to use them in any other of their works. There

has been no ruling by the courts in recent years on this point and it is possible the courts may take a different view.

MR. L. C. MOORE, M. Eng. So. W. Pa.—How do they draw the line between a device and a principle?

MR. F. W. WINTER—It is the law that a principle, pure and simple, is not patentable; but that mechanical embodiments which employ that principle are patentable. Whether a patent covers a principle, or a mechanical embodiment for carrying into effect a principle, is something I can not determine without examining the patent. If it were a patent for a principle, it probably would not be valid. I would be surprised to learn that there is an existing patent for simply a principle, because I believe the officials of the Patent Office were educated on this question many years ago when Professor Morse's patent on the electric telegraph was declared by the courts to be void on the ground that it was a patent for a principle. There was nothing wrong with Morse's invention, but the fault lay in the manner in which his claim was worded.

MR. L. C. MOORE—In testing wire for wire rope I found that in applying the tests as we usually applied them, by bending back and forth over a right angle, that the wire broke under certain conditions. It occurred to me to apply what we would call the working load to the wire before we bent it back and forth. I did that and I found cheap, or poor wire, stood a better test than high-class wire. That I patented. Did I patent a device or a principle?

MR. F. W. WINTER—I am unable to answer the question; it depends altogether on the phraseology of the claim. What you describe might be the basis of a valid patent claim. It should be a claim for a method of testing wire. A claim of that character, if your invention was new at the time it was applied for, would support a valid patent. So whether your patent covers a principle depends upon the manner of claiming it.

MR. A. STUCKI, M. Eng. So. W. Pa.—In regard to a joint invention: I heard several parties express their opinion that there is no such thing, and I suppose if you analyze it fine enough, there is not. Just where do they draw the line?

A question very closely allied is that of co-ownership. It looks rather unfair, that the holder of say 1 per cent. interest can make, use, and sell an article in an unlimited way, just as if he were the holder of the remaining 99 per cent. as well, at least judging from an ordinary business standpoint.

MR. F. W. WINTER—Answering Mr. Stucki's last question first: The party owning only 1 per cent. of the patent right can manufacture, use, and sell, the invention entirely independent of the other co-owners. It may seem unjust, and in some instances it undoubtedly is; but there is another side of the question—if the courts had made the rule that it requires the consent of all co-owners of a patent to manufacture and sell, you can readily see that in many cases the co-owners would be at logger-heads, and a valuable patent might be tied up and nothing ever come of it.

Mr. Stucki's first question was whether there is ever a joint invention. I presume that if the matter were analyzed to finality we would probably find few joint inventions. In most cases you would find that there was just one point of novelty which carries the whole combination, and that was suggested by one of the inventors, so that there would not be a joint invention. Our courts, however, have been very liberal in this matter. They hold that where two parties work together in devising a new device, and which includes a number of elements, and one made this suggestion, and another that, so that it would be difficult to determine how much was suggested by each party—that is a case where both should have the benefit and is a joint invention. In reality it is not so very material whether the essential point of an invention was suggested by one or by more. We must assume that because the patent was granted there was something new devised. Somebody had done something which was an improvement over prior devices, and which should be protected by patent. If persons are willing to say "We both made suggestions and we will share the benefits," it would be very harsh, I think, for the court to say, "It is not a join invention and neither of you shall have any benefit from it."

MR. F. V. MCMULLIN—In regard to the statement that "no person should mark an unpatented article with the word 'patent,' or other designation which would lead the public to believe that

the article is patented," does that apply equally to the words "patented" and "patent"?

MR. F. W. WINTER—It depends on the manner in which the marking is done and whether it is done to deceive the public. The form of the words is immaterial. Either the word "patent" or "patented," or any other word that will convey to the public the idea that the device is covered by a patent, comes under the ban of the statute; but you can use the word "patent" in such a way that it will not convey the idea that there is an existing patent; for instance, you may speak of a "patent corn-sheller."

MR. H. C. CRONEMEYER—Mr. Winter states that "most patents cover mere improvements upon prior devices and it frequently happens that there are still in force prior patents which cover fundamental principles of the device and which will be infringed by the improved device if the latter performs the same function by the same or equivalent means." A device having been patented, and the same inventor, after having disposed of his first patent, makes improvements, which make the device more valuable, can he obtain a second patent on the improvements alone, without the consent of the owner of the first patent?

MR. F. W. WINTER—He can. If the improvements are an advancement upon the original device they are just as patentable to him as they would be to any other individual, and it does not require the consent of the owner of the earlier patent. But he may infringe the first patent. This depends upon the claim of the first patent. If you are assuming that the improvement employs the principle covered by the first patent, then he would infringe the first patent by manufacturing the improvement. He could get the patent, but could not use it during the life of the first patent.

MR. F. C. EMERY, M. Eng. So. W. Pa.—If a man originates an idea that is of no particular value to himself, and seeing this throws it aside, and another party gets hold of the article and pushes it to a successful conclusion, this second party, according to Mr. Winter's statement, is barred from patenting the article, not being the original inventor, and will not attempt to put it on the market without holding a monopoly on it.

MR. F. W. WINTER—Applications must be signed and sworn to by the original inventor. I mean by that that the applicant must be the one who originated the invention. I understand the question to be—One man conceived of the invention and went so far as to make a model, and then dropped it. Afterwards another man originated the same idea but would not patent it because he heard that the other party had a model of it several years before. In a case of that kind, if the second party originated the idea himself, independent of the first party's model, so that he could say he was an original inventor, then under the law he would be the first inventor, because what the first party did was nothing more than an abandoned experiment and cannot bar the claim of a subsequent conceiver who perfected the invention.

The theory is that the one to be rewarded is the man who has given the public some benefit, and a man who merely conceives of an invention, builds a model, but keeps it in his own closet, has not benefited the public, so if someone else afterwards follows up that invention and puts it into actual use and gives the public the benefit, the court will sustain his patent.

MR. F. C. EMERY—Suppose two men working side by side and one of them originates an idea, puts it into mechanical form and perhaps makes a model. The other man sees it and recognizes it as a good idea. The original inventor throws the model under the bench and abandons it. In the course of time this second man proceeds to inculcate that idea in some machine. Has he a right to a patent?

MR. F. W. WINTER—No, he would not be the inventor. He is merely a borrower. He did not conceive it, and if he did take out a patent it would be invalid. It may be a hardship because the public may not get the benefit of it, but I don't see how you are going to remedy that by law.

MR. F. V. MCMULLIN—Is it true that the law holds that the product of a machine cannot be a part of the machine? For instance: A device for sugar-coating pills in a medicine factory consisted of a box connected with an air pump, the top of the box being covered with perforations somewhat smaller than the pills. They would run the pills on the top of the box, exhaust the chamber and hold the pills by the air pressure while giving them

a sugar coating, yet the device was not patentable because it could not be worked without the pills.

MR. F. W. WINTER—The rule is that a product of a machine cannot be made an element of the claim of a patent. The Patent Office has never recognized any exceptions. However, even with the rule as it is now, I believe it should be possible to work out a phraseology of claim which would cover that machine and not make it necessary to include the pill as an element in the claim.

MR. A. STUCKI—The claims, Mr. Winter states, should be drawn as broad as possible. But by combining different elements we will narrow the claims. Therefore to cover one element in one claim would insure the greatest scope possible. Can we do that?

MR. F. W. WINTER—One of the troubles with our patent system is the exceedingly stilted form of the claims. If the claims were brief and drove right at the invention or the result that is to be obtained, our courts would turn them down on the ground that they covered the function, and not the means for producing the function. Consequently we have a complicated form of claim.

There is another point to Mr. Stucki's question: Whether a claim can include a single element, or whether it must include a combination of elements, and if the latter, how many elements must be included? That depends upon the circumstances of each case. If a single element is new and capable of general use it can be claimed singly. If, however, you have merely, as in most machines, brought together old mechanical devices, you must claim a combination of those devices, and the number depends upon the result or function secured.

The claim should be for a combination of those elements, and those only, which co-operate to produce the particular result which is new. If your patent solicitor submits to you a draft of claims, you should consider what is the new result or function which is obtained by your machine. Having determined that, next consider how many elements of that machine are necessary to produce that result. If the claims include any element or elements which are not necessary to produce that result, draw your blue pencil through them.

MR. E. F. GWYNN, M. Eng. So. W. Pa.—Most patent specifications contain more than one claim. If all those claims are original, will a person infringing one claim infringe the patent, or will he have to infringe the combined claims?

MR. F. W. WINTER—If a party infringes any one of the claims, he infringes the patent, and is liable for infringement. Many patents have a multitude of claims. A patent for a car truck came to my notice the other day which had 156 claims. There is really no difference between the claims, but granting that those 156 claims were each valid and independent claims, a party who infringed any one, although he did not infringe the other 155, would still be liable for infringement of the patent. One of the reasons why patent solicitors draw so many claims is to give the claims slightly different aspects. The courts do not permit the use of alternative language, but require a claim to be definite and distinct. It cannot be a collection of words which can be twisted this way or that. We are compelled to make various claims so that if the infringers cannot be caught by one claim they will be caught by another.

MR. E. F. GWYNN—Is it lawful to put two distinctive claims in one?

MR. F. W. WINTER—It is possible that if the subject-matter of two separate claims were combined in one, it would not be valid. But much depends upon the particular circumstances of each case, and it might be possible to combine in one valid claim elements of what might be two separate claims. I can imagine an invention wherein two parts of a machine were entirely new as mechanical movements. Each of those parts would sustain a separate claim. At the same time those groups of elements might co-operate to get a new result in the machine as a whole, and in that case they could be combined in a single claim. All three claims would be valid.

MR. E. F. GWYNN—When the claims of a patent were presented to me for approval I was inclined to draw the blue pencil through them. The patent attorney said, "No, you can't do that; it is doubtful if you can get two of them in one, and if you did, anybody can use any one of the parts because he does not infringe the claim, but only part of it."

MR. F. W. WINTER—That is true. Go back to the example I gave a moment ago of two groups of mechanical elements each sufficient to sustain an independent claim; suppose the only claim of the patent to be a combination of the two. Anybody could then make group number one without infringing the combination claim. But if the patent contains a claim for that group by itself, he would infringe. It is always unwise to group in a claim more elements than are necessary, unless you have another claim in the patent which is for the elements by themselves. You do not infringe a claim for a combination unless you use all elements in that combination. A person may manufacture a device covered by a combination claim and if he leaves out a single element of that combination, he will avoid infringement.

MR. A. STUCKI—Can the patentee sue more than one party for infringement where the manufacturer, seller and user are all liable?

MR. F. W. WINTER—He could maintain suit against all three at the same time, and there would be no way of stopping him until he got a recovery against one party; then the other parties might plead that damages had been recovered. Until that time he could carry on all three suits.

MR. L. C. MOORE—If there are eight manufacturers engaged in the same business and they all infringe a patent—if the patentee sues one, does not that answer for suing all?

MR. F. W. WINTER—No, it does not. If he sues one and is successful, the injunction will be granted only against that one and will not extend to any one who was not a party to that suit. He will have to sue each of the other seven if he wants to stop all of them.

COL. R. MUNROE, M. Eng. So. W. Pa.—In case a person gives a shop right with the privilege of putting a certain product in the articles which they are engaged in manufacturing and selling, would that carry with it the right to sell the product unfinished and not put into their manufactured articles?

MR. F. W. WINTER—As you state the question I should say no. It depends on the contract under which you give him the shop right. A shop right is nothing but a contract. The inventor or the owner of the patent agrees to let another person use the in-

vention for certain purposes. He can stipulate in the contract that the manufacturer can use it only in a certain way and under certain conditions. I take your question to mean this: a patent covers a certain material or substance, and a manufacturer wishes to use that material in making certain articles which he manufactures: the shop right gives him the right to use the patented material in manufacturing his articles. Under those circumstances he has no right to sell that material without first turning it into his own articles.

Mr. E. F. Gwynn—Can you embody in the specifications and claims more than the drawing shows?

Mr. F. W. Winter—No, you cannot. That is covered by a rule of the patent office. Every element and feature that you are claiming must be shown in the drawing.

Mr. E. F. Gwynn—For instance: if the specifications and claims covered a plurality of certain things, the drawing has got to show a certain number; at least two. A plurality, of course, will mean any number above one. Could you change that number from what is shown on the drawing and still have a valid patent?

Mr. F. W. Winter—I am afraid that would depend upon the particular circumstances of the case. There might be some cases where a change in the number of features shown would be a departure from the invention originally described; if so it would not be permissible, and would render the patent invalid. On the contrary, there might be cases where it would not be material whether you change the number of a certain mechanical element. As a rule, it is dangerous to modify your patent drawings after they are once filed, unless it is to make them conform to your specification. The courts many years ago laid down a rule that the invention must not be departed from by any amendments to the application while it is pending in the Patent Office. They construe that very strictly, so that it is always advisable, before your application is filed to see that the drawings, at least, are correct. The verbal description may contain many errors; that need not concern you so much if your drawings are absolutely right; but if both your drawings and your written description are faulty, then it is dangerous Even if the Patent Office officials allow you to make changes, it might result in your getting an invalid patent.

Mr. C. B. Albree, M. Eng. So. W. Pa.—Mr. Winter, is it in your opinion desirable to have the scheme they have in force in some of the foreign countries, that the patent shall be worked to be valid?

Mr. F. W. Winter—In one way, it is bad to have the laws such that parties can monopolize a certain field by buying up patents which they do not use. But there is another side; many inventors would not apply for patents at all if they knew that within two years after the granting of their patent they would have to manufacture or forfeit their patent. It is in the later years of the patent that the returns come, and if you make the conditions hard so that the inventor sees that he may forfeit his patent rights before getting any returns, he will hesitate before applying for the patent, and the invention may never see the light of day. I think that the progress of science and the arts is best subserved by making the conditions for taking out and maintaining patents as easy as possible, so as to encourage mechanics and others who have little means to take out the patents and bring their inventions to the light of day. In the end the public is benefited by it.

Mr. H. C. Cronemeyer—It has come to my personal notice that a college professor, who for a number of years was connected with a manufacturing concern in Europe, held up to his students in engineering that the American patent laws were far superior to the German patent laws.

Mr. A. Stucki—I do not think that a tax or any other levy against the patentee would benefit the industrial development in this country, but I do think, that patents are granted rather freely and that lots of them are taken out not because they are really for inventions, but simply to stop any possibility of trouble by being granted to anyone else. This naturally results in a great number of patents and claims, and it will be harder and harder to keep track of all of them.

Mr. F. W. Winter—The United States patent system is very liberal in granting patents for slight improvements in mechanical details, but patents which the courts nevertheless sustain. An eminent foreign authority has stated that this accounts for the superiority of American machinery in mechanical details. Now

by encouraging patents for such things, we are encouraging the people who work with these machines to make improvements. They are constantly looking for new devices. The German mechanic does not see a reward for him, as his patent laws would not allow him a patent if he did make the improvements.

RE-ENFORCED CONCRETE.*

BY ROBERT A. CUMMINGS.
Member Engineers' Society of Western Penn'a.

Owing to lack of time to prepare a formal paper, the speaker will confine himself to some remarks on the practical phases of this subject, hoping that the discussion may bring out new and useful points.

This material has been called by various name, *e. g.*, armored concrete, concrete steel, ferro-concrete, and steel concrete, but recent authors generally prefer the term, re-enforced concrete, which is doubtless the most appropriate of any.

Re-enforced concrete is generally made from a combination of Portland cement, water, sand and gravel or broken stone in which are embedded iron or steel bars in such a manner as to re-enforce the concrete, especially where the structure is subjected to tensile stresses. Portland cement mixed with sand and water makes an excellent paint for preserving iron or steel, adhering to the metal very firmly and protecting it thoroughly against corrosion. It can easily be made water tight, and its durability is beyond question. These properties of cement mortar can be utilized in re-enforced concrete. This material is well adapted for moulding into a monolithic structure, which does not disintegrate when subjected to shocks such as are produced by railroad trains and vibrates much less for a given load than structural steel. Correctly designed re-enforced concrete structures are not liable to sudden failures, as is the case with ordinary concrete, but gives warning by the falling off of the surface concrete long before the point of failure is reached.

The writers on the theory of re-enforced concrete differ quite widely in their views, but it is hoped that many of the points of difference may be settled by a committee which has been appointed by the American Society of Civil Engineers to investigate the subject in connection with the Engineering Congress.

*Meeting of Structural Section, November 22, 1904.

In Europe various public authorities have investigated re-enforced concrete and laid down rules governing the design and materials for structures of re-enforced concrete. The regulations of the Prussian Government are very conservative. The Swiss Government rules for design are based on the method of Ritter, a well known authority on the subject. There are no uniform rules for design in France; each constructor uses his own methods. New York and Philadelphia are about the only cities in the United States that have formulated any reasonably definite rules on the subject. These rules are incorporated in the building laws and, in the light of well known facts, appear unnecessarily severe.

The speaker feels that the materials and workmanship are the most important considerations in re-enforced concrete construction, and it is essential that they be as nearly perfect as it is at all practicable to make them.

For Portland cement the standard specifications of the Am. Soc. C. E. or those of the U. S. army engineers are good and insure good cement. This is the most important material, as it is that which binds the other materials together, and upon the firmness with which they are bound together depends the strength and durability of the structure. The speaker would call your attention to the boiling test, which is found in some specifications and is sometimes abused. This should be carefully done with clean water free from mud, acid or alkali. If it boils too violently it is liable to break the pat of cement. For that reason the speaker prefers the steam test, which is believed to be fully as efficient a test to determine constancy of volume.

The purity and cleanliness of the aggregate are very important points. Good clean gravel is good, but it is impossible to make good concrete from the gravel that is commonly used in this city dredged from the Pittsburgh harbor and containing large quantities of oil, mud, coal, sewage, etc. Gravel must be thoroughly washed and promptly rejected if it contains oil. Cement will not adhere to anything that is oily. Crushed limestone is good, if it is strong, but it must be always borne in mind that no concrete is stronger than the aggregate of which it is composed. Crushed Beaver valley sandstone is good, but is not very strong in tension. Broken stone makes a stronger concrete than gravel

and for re-enforced concrete the speaker prefers an aggregate that will pass a three-quarter inch sieve. Small aggregates tamp better around the steel re-enforcement. Cleanliness and purity in the sand is at least as important as in the aggregate. The speaker is strongly of the opinion that sand for re-enforced concrete should be graded and regulated much as is done abroad. Concrete is like any other manufactured article, it is impossible to obtain satisfactory results without first-class materials properly put together. The French seem to have taken the lead in grading sand for mortars. M. Feret, chief of the laboratory Ponts et Chaussees at Boulogne, has recently published the results of some tests in which the sand and aggregate were carefully graded. In these tests everything that is retained on a 5 millimeter (2 inch) sieve is graded as aggregate. Everything that passes a 5 millimeter mesh sieve and is retained on a 2 millimeter mesh sieve is graded as coarse sand; all between two millimeters and one-half millimeter (.02 inch) in size is graded as medium sand and everything finer than that as fine sand. His tests indicate that coarse sand makes a considerably stronger mortar than medium sand, and still stronger than fine sand, that a mixed grade of sand makes the mortar stronger yet, and that the maximum of strength is obtained when the sand is of the coarse and fine grades exclusively, the quantity of the former being double that of the latter.

The proper proportion of the ingredients will depend upon the nature of the work. Water tight work requires a large proportion of cement, and the greater proportion of cement the greater the compressive strength.

The speaker is of the opinion that the usual method of specifying the proportions of the ingredients of concrete—entirely by volume—is erroneous. He thinks the cement should be specified by weight and the other ingredients by volume. He knows of a contract in which the engineer specified a certain number of barrels of cement to the cubic yard of sand, etc. The question as to whether packed barrels or loose barrels were meant was decided in favor of the contractor, who thus saved 800 barrels of cement in a very small contract.

The strength of concrete depends largely on the strength of the mortar which it contains, therefore the proportions of sand,

cement and water should be determined first. The maximum strength of the concrete will be obtained when the mortar just fills the voids in the aggregate, but on account of the impossibility of obtaining absolutely perfect mixing, the mortar must be in excess; in fact, to make a concrete absolutely free from voids, about 40 per cent. excess mortar is needed.

Concrete is usually made so wet as to be sloppy. This is done to reduce the amount of ramming necessary, but it is not the best practice. It gives the cement a tendency to work to the top, and the aggregate to settle. This is peculiarly objectionable in columns. Wet concrete, however, is almost a necessity in re-enforced concrete on account of the practical impossibility of properly ramming dry concrete around the re-enforcements. It is, therefore, usual to use a plastic concrete and a large margin of safety in the design. The French determine the proper consistency of mortar for concrete work by specifying that if a sample of mortar be taken out five minutes after mixing, its appearance must not change on standing three minutes longer. Another method is to place some mortar on a trowel and drop it off; if it falls off clean it is wet enough. Another method is to mould a ball of mortar gently in the hand; water should just appear on the surface of the ball. Still another method is to drop the ball twenty inches onto a hard surface; the ball should retain its shape.

For re-enforcement the speaker is in favor of using a medium open-hearth or Bessemer steel such as is used for ordinary structural steel work. Some use a very high carbon steel, but he is not in a position to indorse it.

A COMPARISON OF REINFORCED CONCRETE FORMULAS.*

BY L. D. CORNISH.
(Non-Member.)

I have, during the past year, been making some investigations as to the derivation of the numerous formulas used in designing or reviewing a reinforced concrete beam, the object being a comparison of the various formulas advanced by different engineers.

The engineers to whom these comparisons have been shown have expressed their interest in them and I have been asked to present them before this society.

In a beam of given cross-section and area of reinforcement the first thing determined is the location of the neutral axis.

There are two well-known methods of obtaining this. The first and most used is based on the two assumptions, that the total compression is equal to the total tension in simple cross-bending and that a plane section before bending remains a plane after bending.

The tensile stress in the concrete is neglected.

Among the formulas derived by this first method may be mentioned the so-called Prussian formula, which is required by the Prussian rules and regulations for building construction; those advanced by Edwin Thacher, Emile Perrot, A. L. Johnson, Capt. Sewell, of the Corps of Engineers, U. S. A., Prof. Hatt, Fr. von Emperger, Christophe, Considere and those published in two recent books on reinforced concrete; one by Chas. F. Marsh and the other by A. W. Buel and C. S. Hill.

The second method is to consider the steel reinforcement replaced by an area of concrete equal to the area of the steel multiplied by the ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete. This concrete to be considered as a projecting flange in the plane of the steel, the neutral axis being then considered as at the center of gravity of the new section.

*Meeting of Structural Section, November 22, 1904.

The formula of Prof. Ritter, which is adopted by the Swiss Government and the formula of the late J. B. Johnson, are both based on this method.

The various formulas mentioned as deduced by the first method, with one or two exceptions, show, to the casual observer, no similarity. The nomenclature, as well as the forms of the equations, being different.

Desiring to compare these formulas to ascertain wherein they differed, I adopted a nomenclature to suit myself, although differing somewhat from all the others, which was to be expected.

These formulas for locating the neutral axis I found could all be reduced to the same general form of $X=\frac{KnA}{b}\left(\sqrt{1+\frac{2bd}{KnA}}-1\right)$

NOMENCLATURE.

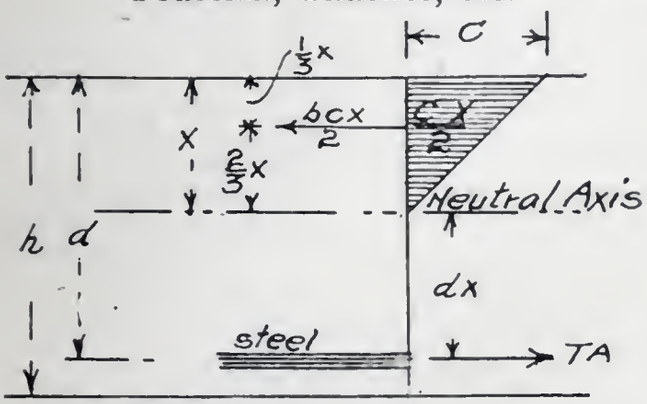
T=Tensile stress in steel, pounds per sq. in.
C=Compressive stress in concrete, pounds per sq. in.
A=Area of steel reinforcement.
Es=Modulus of elasticity of steel.
Ec=Modulus of elasticity of concrete.
$N=\frac{Es}{Ec}$
X=Distance of neutral axis from compression side of beam.
d-x=Distance of neutral axis from center of steel.
M=Resisting moment of beam.
h=Height of beam in inches.
b=Width of beam in inches.
d=Depth of steel below compression side of beam.
d-Fx=Distance between centers of tension and compression.
Fx=Distance from center of compression to compression side.
F=Constant less than unity.
K=Constant in the formula for "X."

$$X=\frac{KnA}{b}\left(\sqrt{1+\frac{2bd}{KnA}}-1\right)$$

$$M=TA(d-Fx)$$

COMPRESSIVE STRESS DIAGRAMS.

Prussian, Thacher, etc.

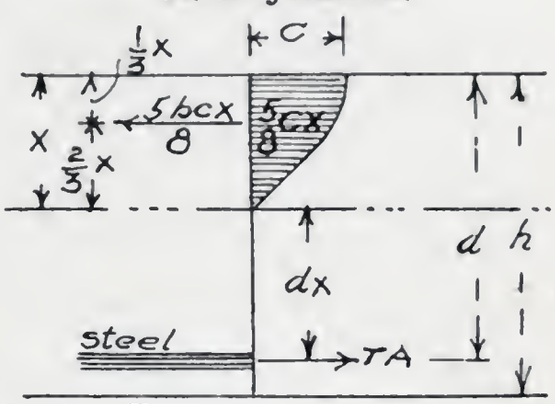


K=1 F=0.33
M=TA(d-0.33x)

$\frac{M}{bd^2}$=301

T=35000 lbs. C=1676 lbs.

A. L. Johnson.

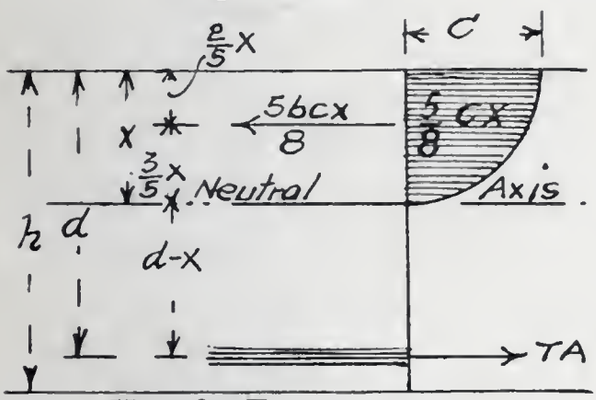


K=1.2 F=.33
M=TA(d-0.33x)

$\frac{M}{bd^2}$=297.6

T=35000 lbs. C=1262 lbs.

Capt. Sewell.

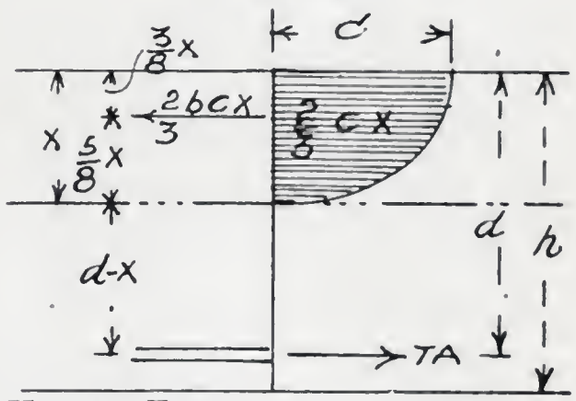


K=0.8 F=0.4
M=TA(d-0.4x)

$\frac{M}{bd^2}$=296.5

T=35000 lbs. C=1455 lbs.

Prof. Hatt.

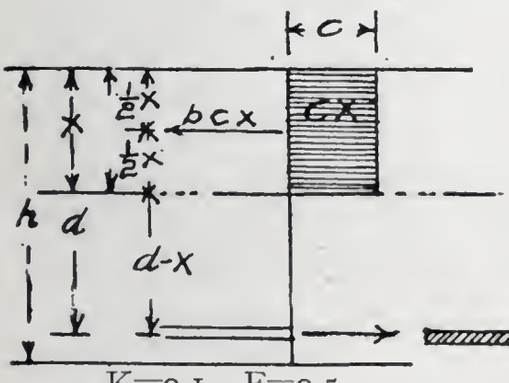


K=.75 F=0.375
M=TA(d-0.375x)

$\frac{M}{bd^2}$=300.5.

T=35000 lbs. C=1400 lbs.

Von Emperger.

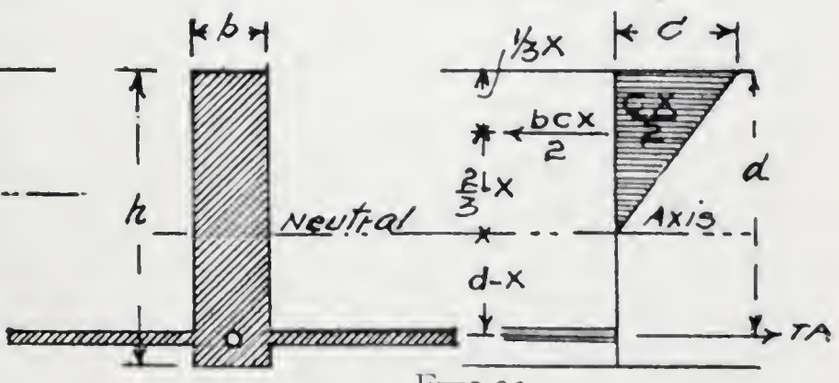


K=0.1 F=0.5
M=TA(d-0.5x)

$\frac{M}{bd^2}$=276.8

T=35000 lbs. C=847 lbs.

Prof. Ritter.



F=0.33
M=TA(d-0.33x)

$\frac{M}{bd^2}$=284.2

T=35000 lbs. C=1238 lbs.

Compressive Stress Diagrams.

In the value of K is shown the only difference between the various formulas for (X).

K varies in the different formulas because of their authors different conceptions of the stress diagram of compression. In the Prussian, Thacher, Perrot and Buell and Hill formulas it is considered a triangle with an area of $\frac{CX}{2}$ and a lever arm with respect to the neutral axis of 2/3X. A. L. Johnson considers it as shown on the sketch with an area of $\frac{5}{8}$CX and a lever arm of 2/3X; Capt. Sewell, as a compromise between a parabola, with the vertex at the neutral axis and a triangle, the area being $\frac{5}{8}$CX and the lever arm 3/5X. Prof. Hatt, as a parabola with vertex at the outermost compression fibre an area of 2/3CX and a lever arm of $\frac{5}{8}$X. Von Emperger, as a rectangular area of CX and a lever arm of $\frac{1}{2}$X.

Considere and A. L. Johnson in their formulas utilize the resistance of the concrete to tension. Tests show that fine cracks appear when medium steel is stressed up to about one-half its elastic limit and the tension value of the concrete is certainly lost then if not before. Therefore in this comparison I have taken liberties with the A. L. Johnson formula by omitting the tension in the concrete and where I mention or use this formula I mean the formula modified as stated.

The constants K are shown on the stress diagram and are for the Prussian and Thacher formula unity, for that of A. L. Johnson 1.2, for that of Capt. Sewell 0.8, for that of Prof. Hatt .75 and for that of Von Emperger unity.

The formulas for the resisting moment of the beam may be made to take the form of either the total tension or the total compression multiplied by d—Fx. In the first case it would be TA (d—Fx) as shown on the sketch, and in the second the TA being replaced by its equivalent, b, multiplied by the area of the compressive stress diagram.

Under each stress diagram is shown the value of $\frac{M}{bd^2}$ for 1 per cent. of steel stressed to 35,000 lbs. per sq. inch. This value shows

numerically the difference in the various formulas, which difference you will note is very small for the first four formulas, being for the Prussian and Thacher 301, A. L. Johnson 297.6, Capt. Sewell 296.5 and Prof. Hatt 300.5.

The formulas for X which consider the steel as replaced by concrete, show no similarity to the preceding ones. The neutral axis is by this method always below the center of the beam, whereas by the first method it is sometimes above and sometimes below the center, depending upon the percentage of reinforcement and tests have substantiated this variable position of the neutral axis.

To show, graphically, the comparison of these various formulas, I have plotted the resisting moment lines for a tensile stress in the steel of 35,000 lbs. per sq. inch, using various percentages of reinforcing.

The lines of the Hennebique and Considere formulas are not shown, as I have not yet completed their reduction to a satisfactory form.

DISCUSSION ON PAPERS OF MESSRS. CUMMINGS AND CORNISH.

Mr. Samuel Diescher, M. Eng. So. W. Pa.—Is the location of the neutral axis determined by the moduli of elasticity or by the ultimate strength of the materials? And why do the moment diagrams given by the different authorities differ so widely?

Mr. L. D. Cornish—The location of the neutral axis is determined by the moduli of elasticity of the materials, but there is quite a wide variation of the modulus of elasticity of the concrete depending on the age, previous loading, composition, method of construction, quality of the materials, etc., besides the stress strain curve of concrete has a considerable curvature from the start, while that of steel is practically straight up to near the elastic limit. The various authorities have fixed the moment diagrams so as to give the nearest approximation to their interpretation of the results of the various tests that have been made to determine the modulus of elasticity of the concrete, and to give results approximating as nearly as possible to the results of numerous tests of the strength of actual re-enforced concrete beams of various forms, and notwithstanding the wide variations in the form of the

moment diagrams, the strength of a beam as determined by the various formulas shows surprisingly small variations as the speaker has shown in his paper.

Mr. Samuel Diescher—Why is not the tensile strength of the concrete taken into consideration, and how are the longitudinal and transverse shearing stresses resisted?

Mr. L. D. Cornish—Concrete is very weak in tension, in fact, when steel bars are imbedded in it and the whole subjected to a tensile stress, the concrete shows minute cracks long before the steel has reached its ordinary working stress. This is shown experimentally. Therefore, although the tensile strength of the concrete adds something to the strength of the beam, the addition is so slight and so uncertain in amount that it is usually ignored, especially that it is an error on the safe side. The steel re-enforcement is usually so arranged as to resist both the longitudinal and transverse shearing stresses, at least near the ends of the beam where they are the greatest; the manner of doing this differs according to the system of re-enforcement adopted. Near the middle of the beam the strength of the concrete alone is generally sufficient to resist all shearing stresses.

Mr. W. Whited, M. Eng. So. W. Pa.—The modulus of elasticity of concrete varies from about 2,500,000 to about 3,500,000, so it is easily seen that refined mathematical analysis is superfluous. The best that can be done is to establish as rational a formula as practicable and assign such values to the constants as to give a large factor of safety.

Mr. W. G. Wilkins, M. Eng. So. W. Pa.—It used to be said in connection with the calculations of structural and bridge work that the safety factor was a factor of ignorance and this remark will also apply to concrete steel construction. In concrete steel construction in addition to the safety factor it seems to the speaker that there is another factor to be given consideration, and it is an exceedingly important factor, and one which should certainly be taken account of in designing a structure to be built of re-enforced concrete. This factor might very properly be called a "factor of carelessness." It makes no difference how exactly the sizes of the various parts of the work are calculated, or how good the materials are of which the structure is built, it is certain

that unless these materials are very carefully mixed and used the result will be a failure in some part of the structure. This is particularly true where the work is not of sufficient magnitude to warrant the concrete being machine mixed, but is mixed by hand, using cheap labor. If the sand, cement and gravel are not uniformly mixed and tamped there will be some parts of the work that will be weaker than the rest. There would also seem to be a chance for imperfect work where one day's concrete is deposited on the work done the previous day and which has had a night or a Sunday to set, resulting in an imperfect or perhaps no bond at all between the two days' work. For these reasons it seems imperative that there should be very rigid inspection not only of the material, but also of the labor employed in the mixing and placing the concrete to prevent carelessness by the workmen employed which may result in failure of some part of the structure.

As to the fire resisting qualities of concrete, the speaker has recently made some rough tests on concrete and sandstone in connection with coke oven construction. Several concrete blocks about 18″x18″x18″ were made and these with some sandstone blocks the same size were covered with old railroad ties saturated with oil and set on fire. The concrete blocks came through the test intact, while the sandstone blocks were shattered into small pieces.

Mr. R. Khuen, Jr., M. Eng. So. W. Pa.—I would like to ask what was used for an aggregate in that concrete?

Mr. W. G. Wilkins—It was ordinary gravel taken from the creek near the works.

Mr. R. Khuen, Jr—The fire resisting qualities of re-enforced concrete depend largely on the material of the aggregate. Granite, for example, as is well known, crumbles to pieces very quickly in a fire. Limestone is also liable to cause trouble in the same way. The speaker would also suggest that the minute cracks in the tension side of a beam might, if exposed to the weather, admit moisture and cause the corrosion and destruction of the steel re-enforcement.

Mr. W. Whited—I would suggest the ordinary blue stone, which is very abundant in this vicinity as a good material for ag-

gregates. It is hard and strong. It does not stand well if exposed to the weather, but aggregates are not so exposed.

It is a well known fact that iron rust has about four times the volume of the iron from which it is made, therefor if the steel re-enforcement rusts to any injurious extent, the expansion of the rust would flake off the concrete and reveal the fact. The fact that few if any re-enforced concrete structures have failed in this way, is first rate evidence that the fears of many people on this point are groundless.

As to the cracking of the concrete on the tension side of a beam, the cracks are not close enough together to impair the resistence of the concrete to longitudinal shearing stresses and the re-enforcement must be so placed as to resist the transverse shear wherever the cracks in the concrete have seriously impaired its transverse shearing strength.

MR. R. KHUEN, JR.—Is it not impracticable to build re-enforced concrete work in winter on account of the fact that cement will disintegrate if subjected to alternate freezing and thawing before it sets?

MR. R. A. CUMMINGS—There are various methods used for the manufacture of concrete in winter. All aim to accelerate the setting of the cement by increasing the temperature of the mixture so that it takes place before being subjected to frost which does not seriously affect it afterwards. Of these methods, the addition of salt to the water when mixing is quite common; another is, the heating of the aggregates, sand and water, both methods being followed by a provision for protecting the concrete—usually heated air from salamanders, etc. The speaker is opposed to both these methods for re-enforced concrete work, using steam instead. His objection to the use of salt is based upon its affinity for moisture and possible future trouble for the steel re-enforcement, besides an unsightly efflorescence on the finished work. As to the heating of the aggregates and sand—there is a great risk of over heating these, causing a too rapid evaporation of the water required for the concrete to set, which results in a weak concrete likely to disintegrate. The same objection is made to all applications of heated air.

MR. J. B. ANDERSON, M. Eng. So. W. Pa.—Where concrete is put in wooden forms the wood itself protects from freezing all but the top, and that is very easily protected by throwing dry sand over it and covering it over with canvas or something of that kind till it sets, which generally occurs in four or five hours, when all danger of injury by freezing is past.

MR. R. W. BRIDGE, M. Eng. So. W. Pa.—About five years ago I put up some work for the National Glass Company at Cambridge, Ohio. The whole of the floors between the I beams was carried by corrugated iron arches, with four-inch rise and about three inches of concrete on the crown. It was very frosty weather, about 10 or 12 degrees below zero. I placed myself on record at the time to the effect that I would not be responsible for the concrete. The proprietors were so anxious that it should be finished that they gave me all the assistance possible, furnishing all the gas I could use. It set pretty well. Steam came from it. It froze solid and stayed frozen for about six weeks, then a thaw came and the concrete returned to the condition it was when it was put in, and to my astonishment, about a day afterward it started to set, and two or three months after that I had occasion to drill some holes through it and found it very difficult to drill.

WOOD MILL BUILDING CONSTRUCTION AS EXEMPLIFIED BY THE PLANT OF THE SLIGO IRON AND STEEL CO. OF CONNELLSVILLE, PA.*

BY A. E. DUCKHAM.
Member Engineers' Society of Western Penn'a.

At the time that I undertook to design the buildings the use of wood was decidedly a case of compulsion due to several causes, the chief of which was the scarcity (at that time) of steel and its slow delivery and the idea of economy which influenced my clients. In fact I was prejudiced against wood in construction, having worked for a number of years with several of our large bridge and structural works in steel construction. Yet, no doubt, wood has its place in construction of buildings; one of the main advantages being slow combustion—for though wood will burn rapidly in small sticks, yet in large timbers of solid construction it only smoulders or chars, while, as often proven by experience, a comparatively small fire will often warp the steel frame-work of a building unprotected (as a mill-building is) by fire-proofing.

One objection to the use of timber where subjected to strains, as in roof-trusses, is the uncertainty of the material in practice, and the difference between that found in actual work and that used in the laboratory experiments, as well as the difference in size. It is indeed fortunate that the Bureau of Forestry of the Department of Agriculture has again taken up the subject of timber tests. The first part of the work was in the hands of the late Prof. J. B. Johnson (whose death was a great loss to our engineering profession); but the present tests are being made under the supervision of Prof. W. K. Hatt. As previously stated, the conditions under which our timber is obtained is so varied by nature (even if not by man) that figures as to strength are a very uncertain quantity. The pieces chosen for the tests, usually being small in section, are selected and clear; while those which go into our building are often more or less full of knots, wind shakes, sap-

*Read before the Structural Section of the Engineers' Society of Western Pennsylvania, December 27, 1904.

wood, or similar defects, which even with vigorous inspection cannot be entirely excluded. The relation between the resistance of timber and the degree of seasoning has to be considered also.

In taking up the different parts of our building of wood construction we naturally start at the base—in this case the column or post which supports the roof. The formula for determining the strength of wooden columns with square ends, deduced by tests made at Watertown Arsenal, Mass., is:

$$S=U-\left(\frac{Ul}{100\,d}\right)$$

in which S=ultimate strength of column per square inch of section.

U=ultimate compressive strength of material per square inch.

l=length of column in inches.

d=dimension of least side of column in inches.

Providing the length is not under 10 or over 45 times the least side.

In other words, $\frac{l}{d}$ should not be less than 10 nor more than 45. If the length is less than 10 times the least side, the direct compressive strength of the material per square inch multiplied by the sectional area of the column in square inches will give the strength of the column. If the length is over 45 times the least side, this formula will not apply; in such cases, provision must be made for bracing the column in all directions, or the load upon it reduced. This seldom occurs in practice. Having obtained S, the breaking load per square inch of section, the safe load per square inch will be obtained by dividing by the required factor of safety—4, 5 or 6. This multiplied by the sectional area will give the safe load for the column.

No column should be less than eight inches on a side, from the Fire Underwriter's point of view. As to the material, yellow pine is best; but sometimes white pine, spruce and oak are used. The value of U, as taken from a table prepared from actual experiments, for northern, or short-leaf, yellow pine is 4,000. If southern, or long-leaf, yellow pine were used, 5,000 would be the figure. Tables being prepared for the strength of different sizes of columns, the breaking loads can readily be picked out.

The allowable unit stresses used on this work, expressed in pounds per square inch were as follows:

Timber in tension only, 1,300; timber in compression, 1,100; timber in extreme fiber under flexure, 1,200; timber for shear parallel to the fiber, 130; timber for compression on sides of fibers: (a) when entire side is compressed, 300; (b) only half of side compressed, 400; (c) under a washer, 500.

For wrought iron in tension, 12,000; in extreme fiber under flexure, 12,000; for rivets in shear, 9,000; in bearing, 18,000; and in the outer fiber of bolts under flexure, 15,000.

The bending moment of the rafter is computed by the usual formula of the Mechanics of Materials:

$M=\frac{S\,I}{c}$; when M=maximum Bending Moment.

S=unit stress allowed, I=Moment of Inertia, and c= distance of extreme fiber from neutral axis.

Then $M=\frac{S\,I}{c}=\frac{1200\times\frac{bd^3}{12}}{c}$, where b=width and d=depth of beam in inches.

Where a rafter is 2 inches wide,

$$M=\frac{1200\times\frac{2\times d^3}{12}}{\frac{d}{2}}=400\,d^2.$$

The rods, where not upset, are figured for area at root of thread.

The weight of truss was about five pounds per square foot of horizontal area. The total load per square foot horizontally was taken as 50 pounds; including dead, snow and wind loads.

Using Merriman's formula for wooden trusses:

$W=\frac{1}{2}\,al\,(1+\frac{1}{10}l)$, where a=distance between trusses (or "bay") and l=span.

$W=\frac{1}{2}\times 20\times 80(1+8)=7200$=weight of one entire truss; then $\frac{7200}{20\times 80}=4.5$ pounds per square foot.

The stresses were figured graphically.

The knee-brace strain was figured as usual:

$K=\frac{S\,l}{R}$; in which, S=horizontal strain from wind applied

at base of column, l=distance from bottom of truss to base of column, and R=radius of arc which, being inscribed with a center at the junction of lower chord of truss and column, touches the knee-brace. It will be noticed that no matter at what inclination the knee-race is made, if drawn tangent to this arc of radius R, the stress will remain the same. This, of course, considers the column hinged at the base, which the writer considers the proper hypothesis; as anchor-bolts are more for the use of the erectors than anything else. The wind-load was figured at 30 pounds per square foot, the buildings being in an exposed position.

One item of uncertainty in figuring the stresses of a truss is whether the truss will be allowed only its legitimate load, or whether the shop foreman in ignorance will affix thereto divers "runways" or make an attic storeroom between the top and bottom chords. The same may be said of the columns; which often carry jib-cranes, for which they were never designed. The "back is" not always "made to fit the burden"!



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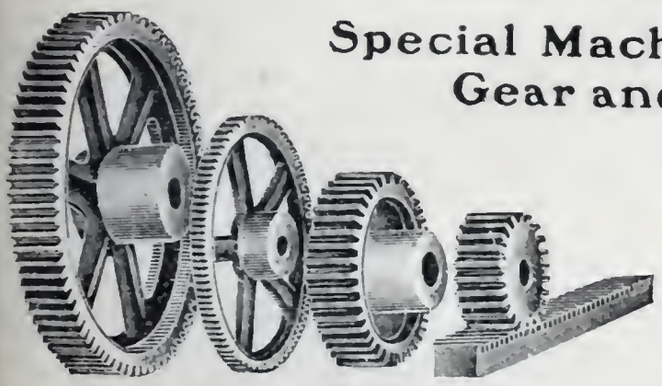
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The magazines are for sale at 50 cents each. Subscription price, $5.00 per annum.

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The following Rules of the Board of Directors are in force:

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An author of a paper is entitled to twenty-five copies, if printed. In addition he can purchase fifty or more copies extra at first cost to the Society, plus 10 per centum, provided the order is forwarded before the type is distributed. These papers can be issued with pamphlet covers when desired.

With the publication of Volume X, the printing and binding of our TRANSACTIONS as an Annual, by the Society, ceased. The paging of the Monthly numbers, however, will be made consecutive, and at the end of the year a title page and index will be provided, so that members may have them bound into a volume uniform with preceding ones.

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Vol. I, $1.50, Vol. IV. $2.00, Vol. V, $1.00, Vol. VI, $1.00, Vol. VII, $1.50, Vol. VIII, 50c., Vol. IX, 50c., Vol. X, 50c. Complete sets of Vols. XI and XII, unbound, $2.00 each.

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The problem of advertising for engineers and manufacturers is one that should enlist the best efforts of expert advertising men; but it is too often delegated to inexperienced hands or so slightingly treated as almost to nullify any good effects that might otherwise be expected from it.

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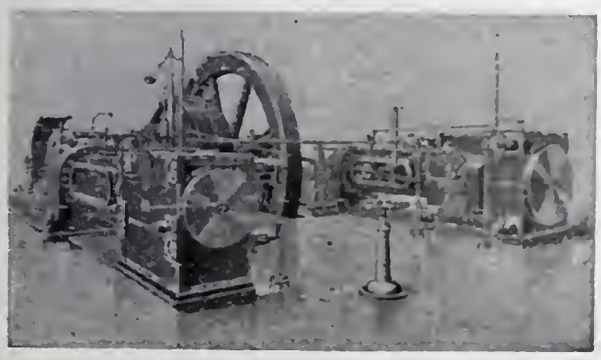
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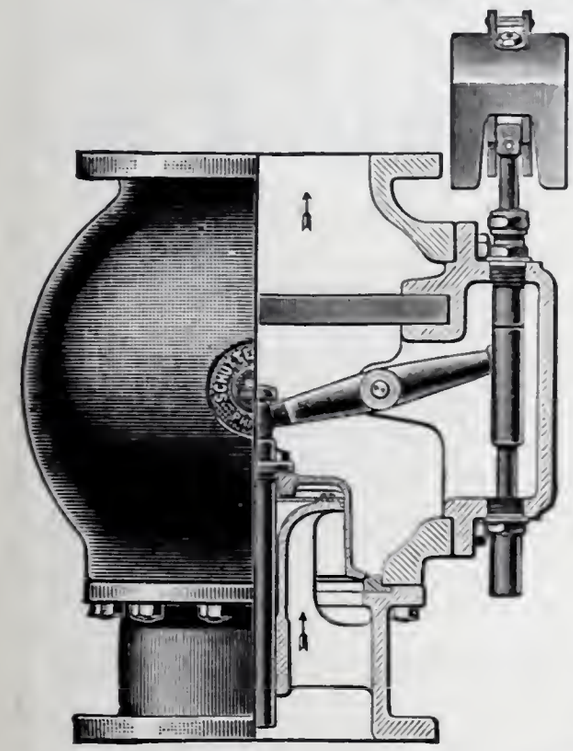
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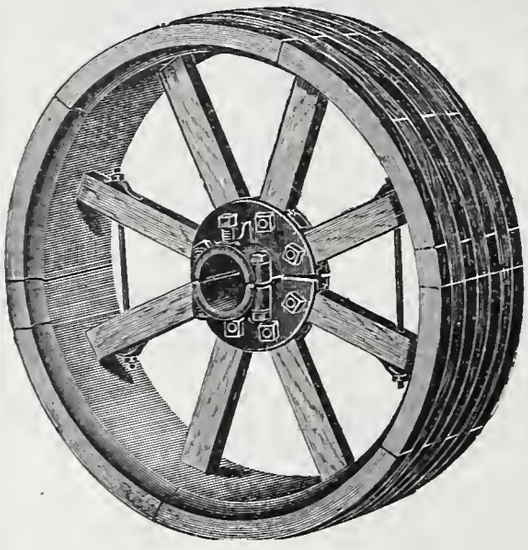
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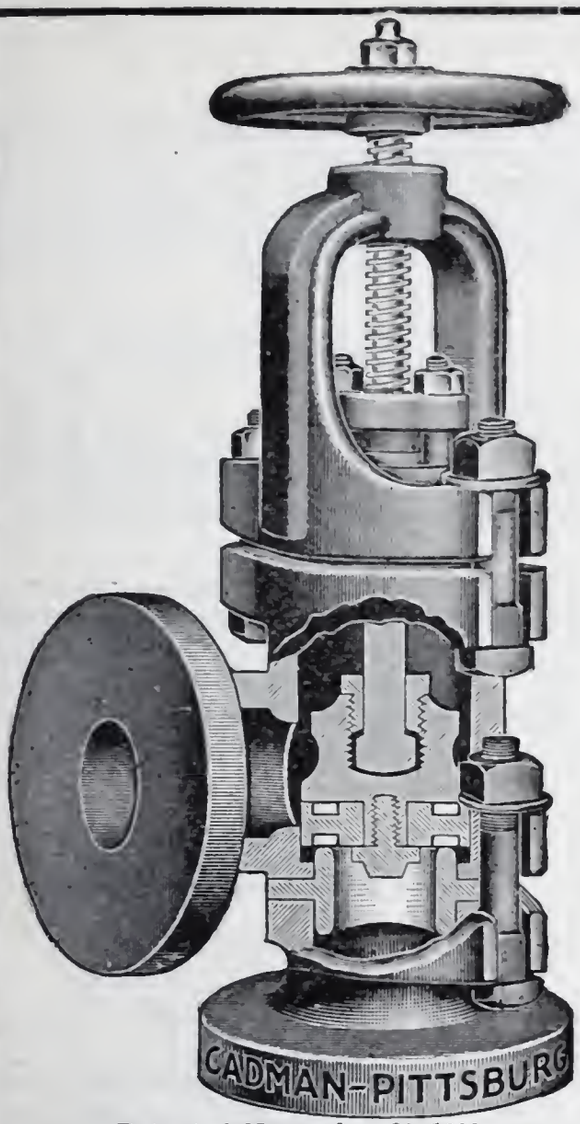
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SCOTT PLACE,
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TURNBUCKLES. **CLEVIS NUTS.**



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Bessemer Building, PITTSBURG, PA.
Telephones, Bell 1865 Court. P. & A. 1645 Main.

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INCORPORATED
ELECTROTYPING AND STEREOTYPING
ARROTT BUILDING, BARKER PLACE, PITTSBURGH
Phones { Bell 2334 Grant / P. & A. 1111 Main



Weinland Instruments For "Boiler Surgery"

The worst cases of Scale can be operated upon successfully with



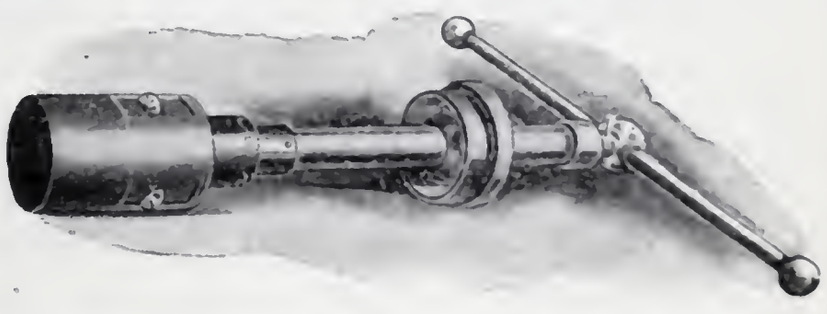
Weinland Tube Cleaners.

Water drives the machine, and a steady grinding process cuts the scale from the iron without expanding, loosening or injuring tubes in any way. They have restored thousands of boilers to perfect condition, and what they have done for others they'll do for you. This cut shows our No. 8—THE KING OF TURBINE CLEANERS, besides which we manufacture others—Hand Cleaners and Power Driven Cleaners—All kinds and sizes for all styles of boilers and all sizes of tubes. "No Tube Cleaner like 'A WEINLAND' "—Anybody who's used one will tell you that.

FOR "AMPUTATING" TUBES USE

The Lagonda Tube Cutter.

Cuts at any point of the tube.



It does the work quickly, easily, and cuts clean every time—leaves no burr. Does not bend or mar the tube in any way. A simple, inexpensive tool needed in every boiler room.

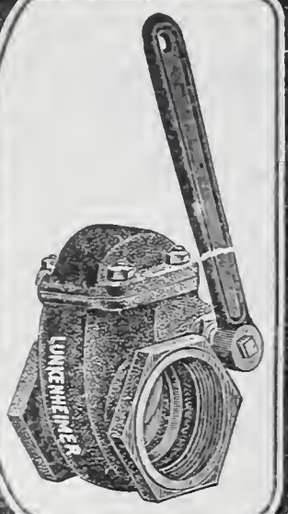
TRY OUR DAMPER REGULATOR FOR "CONSUMPTION" OF COAL—SURE CURE! GET CATALOGUE.

The Lagonda Mfg. Co.

Springfield, Ohio.

Pittsburg Office at 112 Wood Street
ROBERT GREGORY, Manager.

LUNKENHEIMER



These are the original, reliable, quick-opening valves, constructed on practical principles.

The "Handy" for 75 lbs. working pressures is made in Brass, ½ to 4 inches; in Iron, brass mounted, 2 to 8 inches; All Iron, 1 to 8 inches.

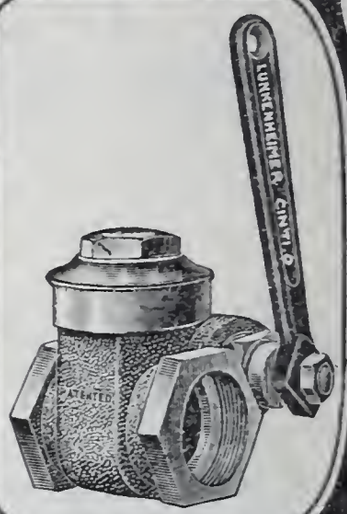
The "Lever Throttle" for 175 lbs. working pressures is made in Brass, ¾ to 2½ inches; in Iron, brass mounted, 2½ to 6 inches. Either pattern made only in screw ends. Specify *Lunkenheimer* and order from your dealer. Write for catalog.

The Lunkenheimer Company,

Largest Manufacturers of Engineering Specialties in the World.

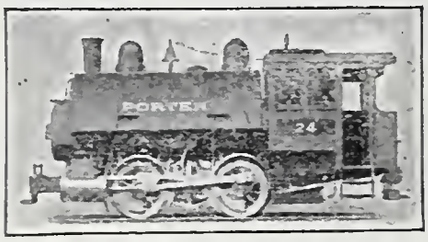
CINCINNATI, O., U. S. A.

Branches:
New York: 26 Cortlandt St.
London: 35 Great Dover St.



"HANDY" GATE and "LEVER THROTTLE" VALVES

11



No. 24 Shifter.

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Illustrated Catalogue mailed free.



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LIGHT LOCOMOTIVES—STEAM AND PNEUMATIC.

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of PITTSBURG.

541 Wood Street, Bank of Commerce Building.

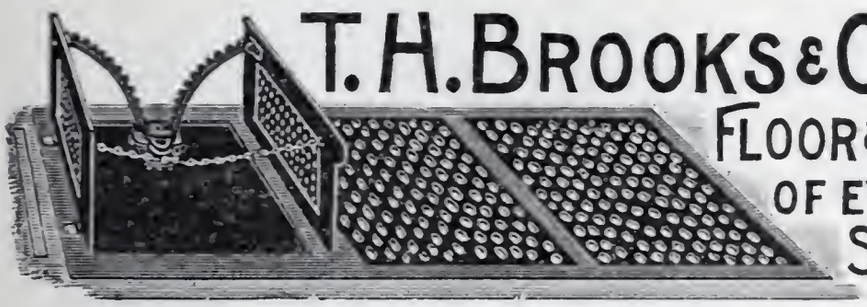
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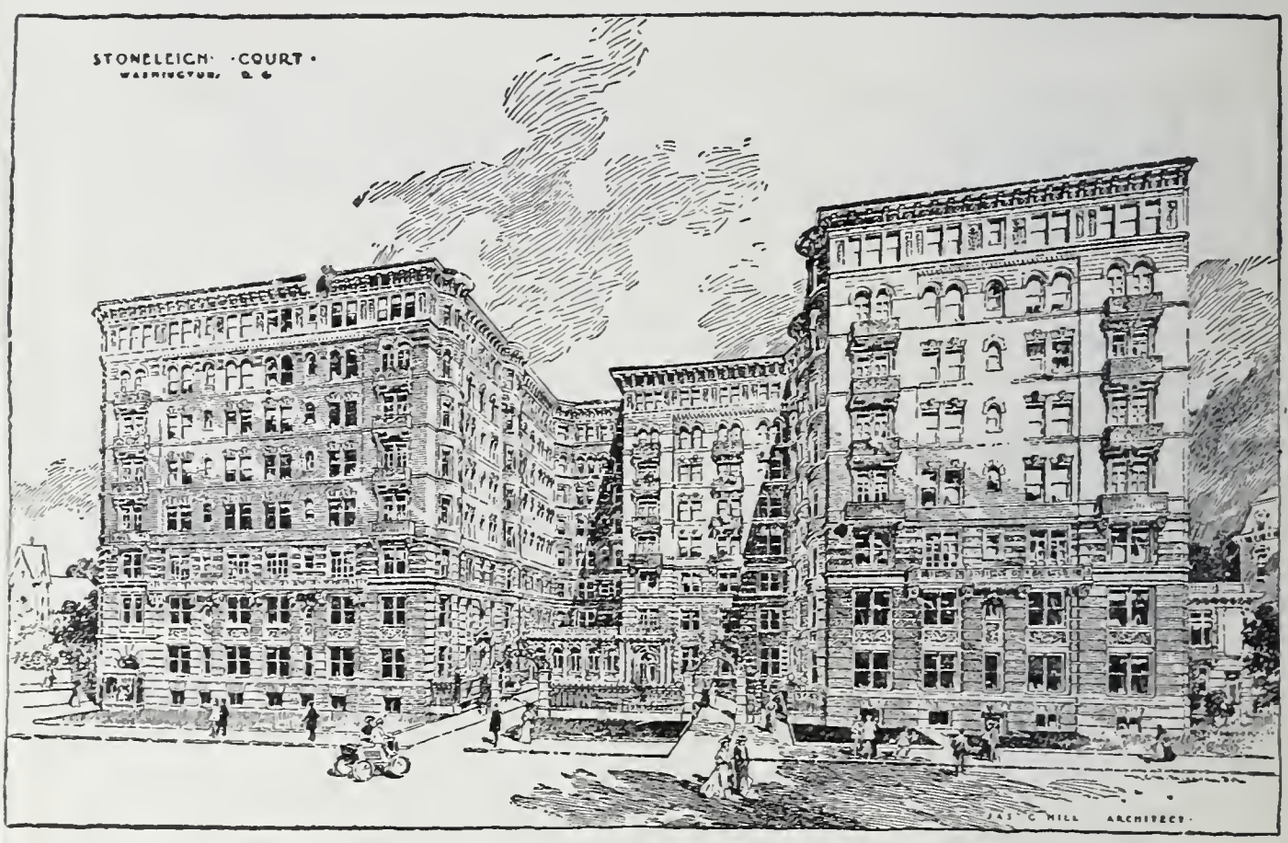
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Chicago, 442-452 Wabash Ave.
Cincinnati, Broadway & Court Sts.
St. Louis, 12th & St. Charles Sts.
Minneapolis, 500-510 S. Third St.
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Milwaukee, 492-494 Market St.
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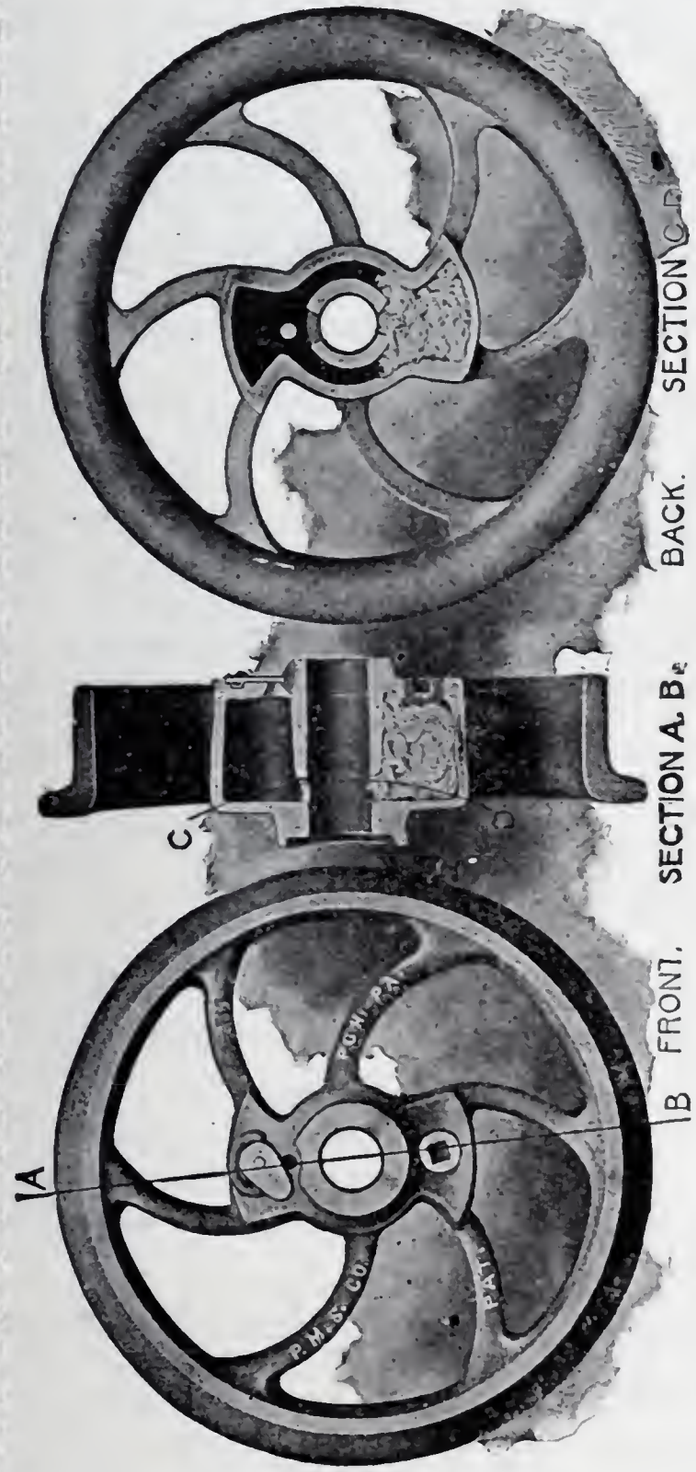
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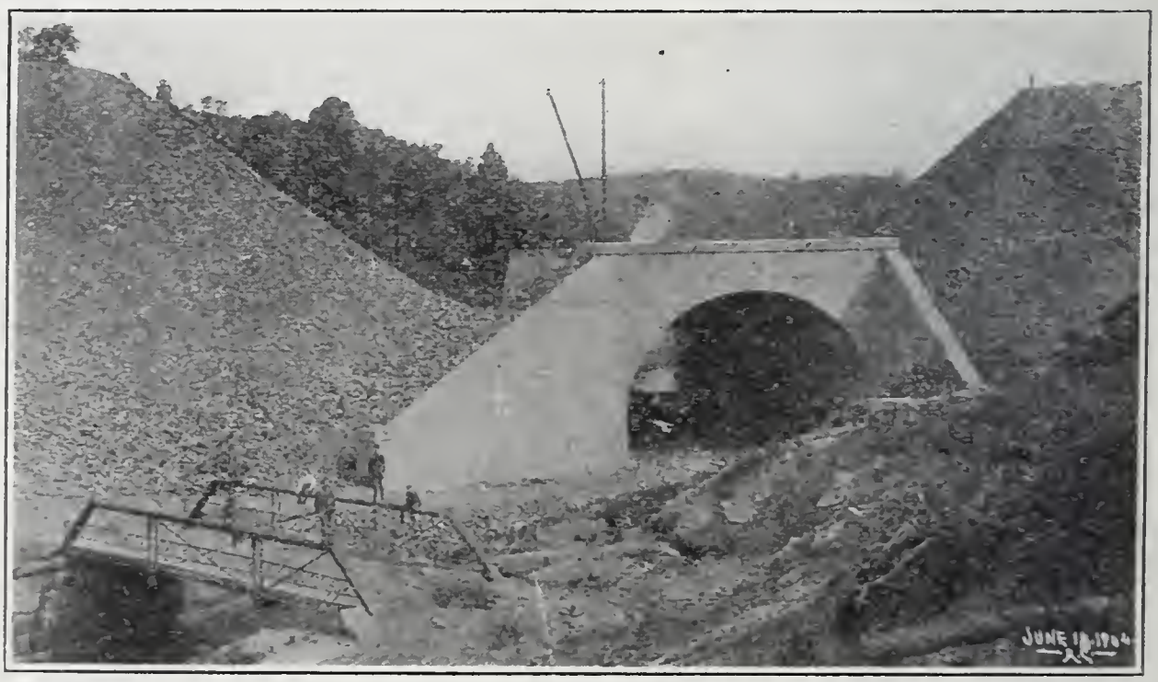
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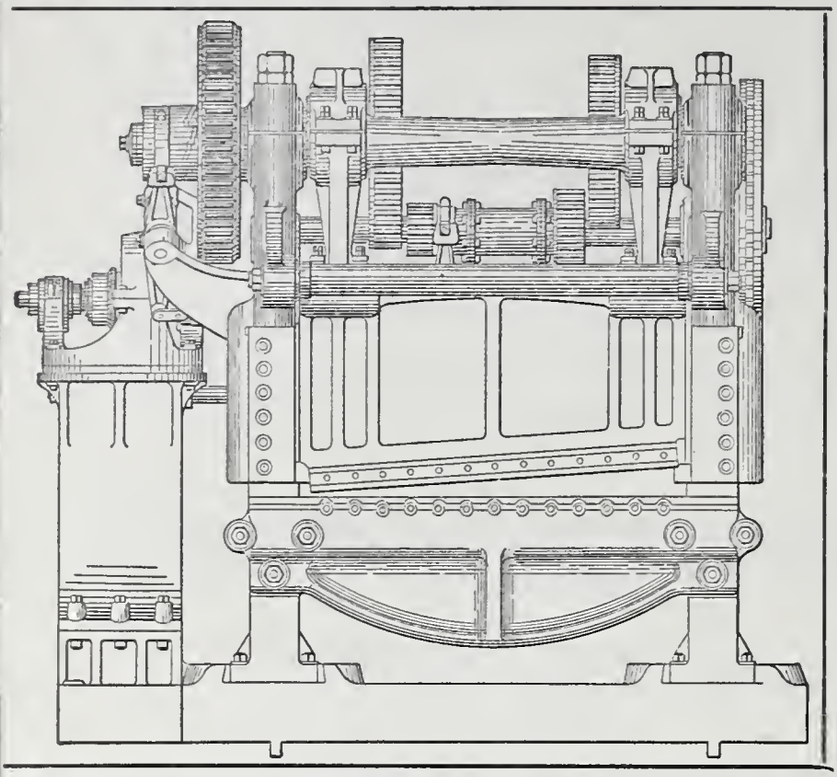
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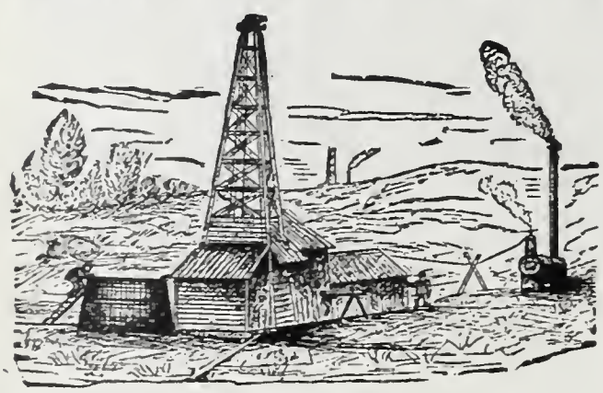
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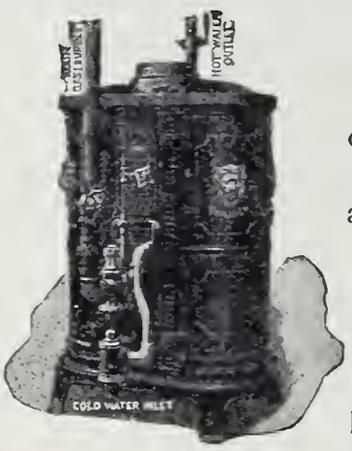
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Vol. XX. JANUARY, 1905. No. 12.



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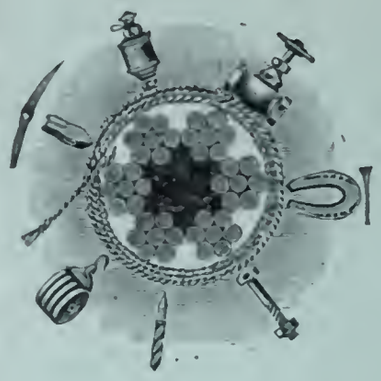
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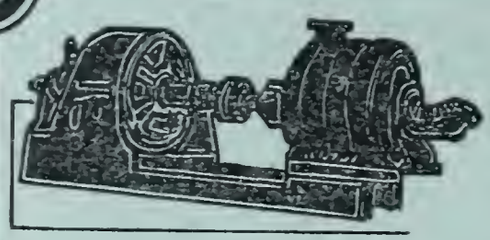
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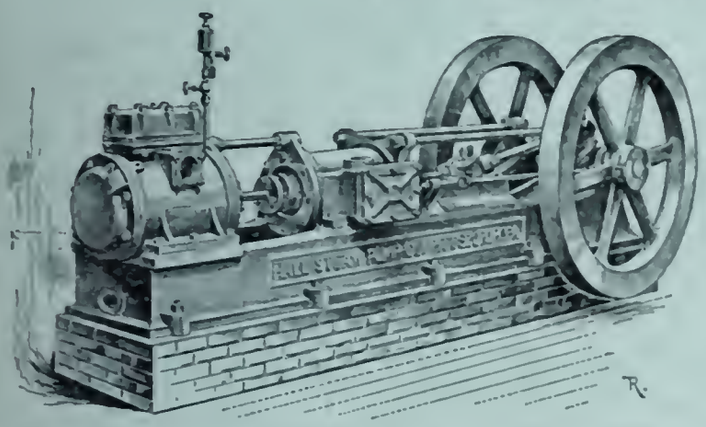
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